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Aberdeen Proving Ground, Maryland

14 January 1952

ERRATA SHEET FOR BRL REPORT 620

p. 10, line 3. For "e", read "10".

p. 10, par. d. After "459", insert, "532".

p. 11, line 4. Note that a table of p and 1/p, "Functions of Stability Factor", is available (BRL File N-II-48).

pp. 11 and 12. The following empirical formulas, which give approximate values of the normal force coefficient and the distance from the base to the center of pressure for projectiles with ogival and conical heads, should be substituted for those given in the report:

$$K_N = .653 + .0223a - .6139b - .0023c + .2635d + .6476\ (1/e),$$

$$h = .0747 + .0443a + 1.019b + .8032c + .2459d + .8083\ (1/e).$$

p. 14, par. h. After "408", add "664".

p. 14, bottom. Add "The axial couple damping factor is

$$\ell = -\dot{N}/N = K_A \rho d^4 u/A."$$

p. 26, last line. For "MR" read "BRLM 417".

p. 35, par c. After "A.P. T9E4 Tracer" insert "BRL 416".

p. 55. For "M308 (T23) and T23E1" read "T23 and M308 (T23E1)".

pp. 56 and 58. For "M308" read "T23", and for "T23E1" read "M308".

p.71 After "(APG Photo A8392)" insert "Design 3-76J, NDRC Report A-428".

p. 77, par f. After "Tank Gun M1A2" insert, "T94 and T102", and add the line "76mm Tank Gun T91 -- 25".

p. 85, par. f. Add the line "Gun T119 -- 25".

p. 93, par. d. After "Chem. (WP) M60 M48" insert "BRLM 447".

p. 140 For "597", read "602", and add the following BRL reports:

X120 Maple, C. G., and Synge, J. L. General Equations of Motion for a Projectile with Rotational Symmetry.

491 Sterne, T. E. On Jump due to Bore Clearance.

503 Goldstine, A. K., and Kelley, J. L. Ballistic Data for Flat Fire.

542 Thomas, R. N. Some Comments on the Form of the Drag Coefficient at Supersonic Velocities.

587 John, F. Formulae for Computation of Differential Effects for Forward Fire from Aircraft.

591 Hoffleit, D. On the Determination of Yaw from Yaw Cards.

602 Morrey, C. B. A Formula for the Representation of Resistance Functions.

619 Hitchcock, H. P. Form Factors and Stability of Ammunition for German 3-cm Aircraft Gun MK 103.

628 Synge, J. L. Initial Effects of Overturning Moment on a Shell Fired with Large Initial Yaw.

658 Karpov, B. G. The Accuracy of Drag Measurements as a Function of Number and Distribution of Timing Stations.

664 Kent, R. H., and Galbraith, A. S. A Note on the Stability Conditions for Spinning Shell and Rockets.

684 Turetsky, R. Reduction of Spark Range Data.

703 Zaroodny, S. J. On Jump due to Muzzle Disturbances.

717 Richards, E. Comparative Dispersion and Drag of Spheres and Right Cylinders.

719 Clippinger, R. F., and Gerber, N. Supersonic Flow over Bodies of Revolution.

729 and 730 Clippinger, R. F., Giese, J. H., and Carter, W. C. Tables of Supersonic Flows About Cone Cylinders. Part I: Surface Pressure. Part II: Complete Flows.

p. 141. After "293", for "Hicthcock", read "Hitchcock".

p. 142, par. b. Add the following memorandum reports:

347 Hailperin, T. Comparison of Boattail and Square Base.

365 Siljander, W. A. Effects upon the Moment and Drag Coefficient of an Increase in Width of Driving Band.

426 Hitchcock, H. P. Ballistics of Caliber 0.60 H.E.I. Bullet T91.

435 Turetsky, R. A. Cone Cylinder Model E12M3.

447 Hitchcock, H. P. Stability of 105-mm Chemical Shell M60.

456 Hitchcock, H. P. Form Factor and Stability of A.P.I. Bullet T39 Fired from Shortened Caliber 0.60 Barrels.

464 Zaroodny, S. J., and Sultanoff, M. Ballistic Tests of Cartridge Caliber .50 A.P.I.T., T63.

514 Carter, W. C. Theoretical Supersonic Pressure Distributions on Non-yawing Cone Cylinders with Boattails.

527 Nicolaides, J. D. On the Development of a Low Spin Anti-tank Projectile.

532 Hitchcock, H. P. Formulas for Normal Force and Center of Pressure of Long Bodies of Revolution, Based on DeMeritte and Darling's Experimental Results.

545 Hitchcock, H. P. On Estimating the Drag Coefficient of Missiles.

564 Hitchcock, H. P. Table of Form Factors of Projectiles.

p. 142, par. c. Add the following miscellaneous reports:

NOTS TM RRB-109 Hall, N. S., Friesen, E. W., and Leitmann, G. Cross-wind Firing of 20-mm Guns.

BRL TN 474 Hitchcock, H. P. Windage Jump of 20-mm Practice Projectile T114.

BRL TN 11 Krieger, R. H. Supersonic Wind Tunnel Tests of Small Caliber Projectiles: Cal .50 A.P.I. M23, Cal .60 A.P.I. T39, and 20-mm H.E.I. M97.

BRL TN 392 Patton, R. B. Determination of Drag Functions for 8" Howitzer Shell H.E. M106.

p. 142, par. d. After ref. to Fowler's "The Aerodynamics of a Spinning Shell", add "Part II, A222, 227-247 (1922).

BALLISTIC RESEARCH LABORATORIES

REPORT NO. 620

Aerodynamic Data for Spinning Projectiles

H. P. HITCHCOCK

ORDNANCE RESEARCH AND DEVELOPMENT DIVISION
OFFICE CHIEF OF ORDNANCE
PROJECT NO. TB3-0824

OCTOBER 1947

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ABERDEEN PROVING GROUND, MARYLAND

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BALLISTIC RESEARCH LABORATORIES

REPORT NO. 620

Hitchcock/jmh
Aberdeen Proving Ground, Md.
17 October 1946

AERODYNAMIC DATA FOR SPINNING PROJECTILES

ABSTRACT

This is a collection of the physical and aerodynamic data of spinning projectiles (excluding spin-stabilized rockets) which have been obtained experimentally in the U.S. during the past decade. Some theoretical and empirical formulas are included. The index classifies the projectiles according to their shape. Most of these data were determined from free flight, but a few wind tunnel results are included.

1. Introduction

a. This report contains the physical and aerodynamic data of spinning projectiles (excluding spin-stabilized rockets) which have been obtained experimentally in the United States during the past decade, together with a few of the earlier results. Ballistic Research Laboratory Report No. 27 on "Resistance Functions of Various Types of Projectiles" gives the data on drag which were obtained from resistance firings and air stream experiments before June 1935. Ballistic Research Laboratory Report No. 30 on "Stability Factors of Projectiles" gives the data which were obtained from stability firings before September 1940 (the first edition was dated December 1935).

b. In the present report, the symbols are listed alphabetically for convenience; they are the ones commonly used in the Laboratory. Some of the formulas which define and connect the physical and aerodynamic quantities are collected for reference purposes: these include several empirical formulas that can be used for estimating the values of coefficients when no better method of determining them is available.

c. The data are arranged in the following manner: ordinary projectiles are grouped according to caliber; then, separate paragraphs are devoted to the drag of slugs, the drag of spheres (included as a simple basis of comparison), characteristics of point fuzes, and the drag of typical projectiles. For ordinary projectiles of each caliber, the known data are given in the following order:

(1). A sketch of the projectile, showing the principal dimensions in calibers, and the numbers of the official drawings.

(2). The physical characteristics, including weight, distance from base to center of gravity, and principal moments of inertia.

(3). The drag coefficient and the form factor relative to one of the typical projectiles, with a reference to the report and the method of observation (with a few exceptions, form factors obtained by range firings have been omitted.)

(4). The standard stability factor for a given pitch of rifling, the moment coefficient, and a reference to the report.

(5). The cross wind force coefficient, which was usually determined from drift firings and taken from the referenced report, and the yawing moment coefficient and Magnus moment coefficient, which were determined from the damping of the yaw in connection with the stability firings.

(6). The axial couple coefficient and skin friction drag coefficient, which were determined from the observed loss of spin.

(7). The pitch of rifling of various guns, in terms of the caliber whose true value is expressed in inches.

d. The Mach number -- the ratio of the velocity of the projectile to the velocity of sound in air -- is the principal variable on which the aerodynamic coefficients depend. It is given whenever both the velocity of the projectile and the temperature of the air are accurately known. Otherwise, only the velocity of the projectile is given.

e. The list of reports given herein includes those from which the experimental data were taken, and also some which explain the theory and the methods of performing the tests. The illustrations and graphs

contained in the present report are listed. Finally, the index is convenient when data are desired pertaining to a particular shape of projectile.

2. Nomenclature

Symbol	Nomenclature	Unit*
a	Velocity of sound waves in air	ft/sec
b	Windage jump coefficient (mil. ft/sec)	rad.ft/sec
c_1	Cross wind factor	ft^{-1}
c^2	Couple factor	ft^{-2}
c', c"	Damping coefficients	ft^{-1}
c	Damping coefficient	ft^{-1}
d	Diameter; caliber (inch or mm)	ft
d_1, d_2	Diameters of bearing surfaces (in)	ft
e	2.71828; base of natural logarithms	1
f	Yawing moment damping factor	sec^{-1}
g	Gravitational acceleration (m/sec^2)	ft/sec^2
g	Distance from base to center of gravity	cal
h	Distance from base to center of pressure	cal
h	Density factor (m^{-1})	ft^{-1}
i	Form factor	1
j	Drift factor	1
k	Retardation coefficient	ft^{-1}
k	Radius of gyration about transverse axis	cal
m	Mass of projectile (grain or gram)	lb
n	Pitch of rifling; reciprocal of twist	cal
p	Moment of inertia factor; square of radius of gyration about axis of projectile (cal^2)	1
p	Function of stability factor	1

*These units will produce consistent results. Other common ones are given in parentheses.

2. Nomenclature (Con.)

Symbol	Nomenclature	Unit
q	Nutational frequency	rad/sec
r	Function of damping and stability factors	sec^{-1}
s	Stability factor	1
s_s	Standard stability factor at the surface of the earth	1
t	Time	sec
u	Velocity of projectile relative to air	ft/sec
v	Velocity of projectile relative to gun	ft/sec*
v_o	Muzzle velocity	ft/sec
v_r	Recoil velocity	ft/sec
v_b	Increase in projectile velocity caused by the blast	ft/sec
w	Velocity of air relative to gun; wind (mi/hr)	ft/sec
w	Angular velocity of axis of projectile (deg/sec)	rad/sec
x	Horizontal range (yd or m)	ft
y	Altitude (yd or m)	ft
z	Linear drift (yd or m)	ft
A	Siacci Altitude function ($ft.lb/in^2$ or $m.lb/in^2$)	ft
A	Axial moment of inertia ($gr.in^2$ or $lb.in^2$)	$lb.ft^2$
A	Azimuth (deg)	rad
B	Transverse moment of inertia ($gr.in^2$ or $lb.in^2$)	$lb.ft^2$
B	Drag coefficient ($lb/in^2/ft$); $5.217 \times 10^{-4} K_D$	
C	Ballistic coefficient (lb/in^2)	lb/ft^2
C_L	Drift coefficient	sec^3/ft^2
C'_{DF}	Skin friction drag coefficient	1
D	Angular drift (mil)	rad
D	Drag	$lb.ft/sec^2$
D_F	Skin friction drag	$lb.ft/sec^2$
G	Drag function ($lb/in^2/sec$)	sec^{-1}

2. Nomenclature (Con.)

Symbol	Nomenclature	Unit
G_1, etc.	Drag function for Projectile Type 1, etc.	
H	Density as a function of altitude (ratio)	
Hw	Yawing moment	$lb.ft^2/sec^2$
I	Siacci Inclination function (lb/in^2)	1
J	Magnus moment	$lb.ft^2/sec^2$
K	Magnus force	lb.ft/sec
K_A	Axial couple coefficient	1
K_D	Drag coefficient; 1916.8 B	1
$K_{D\delta}$	Yaw-drag coefficient (deg^{-2})	rad^{-2}
K_{DF}	Skin friction drag coefficient	1
K_H	Yawing moment coefficient	1
K_J	Magnus moment coefficient	1
K_K	Magnus force coefficient	1
K_L	Cross wind force coefficient	1
K_M	Moment coefficient	1
K_N	Normal force coefficient	1
L	Length of nutational period	ft
L	Cross wind force	$lb.ft/sec^2$
L_b	Bearing length (in)	ft
M	Moment of air resistance about center of gravity	$lb.ft^2/sec^2$
M_s	Spin reducing moment	$lb.ft^2/sec^2$
M	Mach number	1
N	Normal force	$lb.ft/sec^2$
N	Spin (rev/sec)	rad/sec
N_o	Muzzle spin (rev/sec)	rad/sec
P	Distance, measured along the line of departure, to a point directly above the projectile (yd)	ft

2. Nomenclature (Con.)

Symbol	Nomenclature	Unit
Q	Drift function	sec^2/ft^2
Q	Drop of projectile (yd)	ft
R	Total air resistance	$lb.ft/sec^2$
R	Reynolds number	1
S	Siacci Space function ($ft.lb/in^2$ or $m.lb/in^2$)	ft
S'	Surface of projectile, exclusive of base (in^2)	ft^2
T	Siacci Time function ($sec.lb/in^2$)	sec
T	Nutational period	sec
Z	Zenith angle (deg)	rad
α	Maximum yaw (deg)	rad
$\lvert\beta\rvert$	Minimum yaw (deg)	rad
γ	Magnus moment damping factor	sec^{-1}
δ	Yaw (deg)	rad
ϵ	Yaw in the bore (deg or min)	rad
θ	Angle of inclination of the trajectory (deg or mil)	rad
θ_o	Angle of departure (deg or mil)	rad
κ	Cross wind force damping factor	sec^{-1}
λ	Cross wind force factor	$lb.ft/sec^2$
λ_1	Magnus force damping factor (strictly, $N\lambda_1$ is the damping factor)	1
μ	Moment factor	$lb.ft^2/sec^2$
ν	Normal force factor	$lb.ft/sec^2$
π	3.1416; ratio of circumference to diameter	1
ρ	Air density ($1,gr/in^3$, lb/in^3, kg/m^3, etc.)	lb/ft^3
ρ_o, ρ_s	Standard air density at the surface of the earth	lb/ft^3
σ	Air viscosity	lb/ft/sec
ϕ	Orientation of plane of yaw (deg)	rad
$\dot{\phi}$	Time rate of change of orientation (deg/sec)	rad/sec
ϕ'	Linear rate of change of orientation (deg/ft)	rad/ft
Δ	Windage jump (mil)	rad

3. Formulas

The following formulas are given without full explanation. They are explained in the BRL Reports whose numbers are given in parentheses (par. 26 lists their titles).

a. Physical characteristics: (X-113)

(1) For a hollow (or solid) cylinder of mass m, outside diameter D, inside diameter d, and length L:

$$gD=\frac{L}{2}, \qquad A = m\,\frac{D^2+d^2}{8}, \qquad B=\frac{A}{2}+m\frac{L^2}{12}.$$

(2) Similar formulas with approximate empirical coefficients for caliber 0.30 and 0.50 ball and armor-piercing bullets are:

$$gd=0.400\ L, \qquad A=0.115\ md^2, \qquad B=0.5A+0.0543\ mL^2$$

Here, d is the caliber and L the length of the bullet.

(3) Likewise, the approximate empirical formulas for high explosive shells of caliber d and length L are:

$$gd=0.375\ L, \qquad A=0.140\ md^2, \qquad B=0.5A+0.0594\ mL^2$$

(4) In general, the squares of the radii of gyration, expressed in calibers, are:

$$p = A/md^2, \qquad k^2=B/md^2$$

b. Drag: (X-113, 261, 276)

$\dot{u}=-D/m - g \sin \theta$ (Dot denotes time derivative)

$K_D=D/\rho d^2u^2$ (A function of the Mach number, $M=u/a$, and the yaw δ; Reynold's number also has a small effect.)

Approximately, if the yaw is not too large, and if K_{D_o} denotes the drag coefficient for 0 yaw,

$$K_D = K_{D_o}\,(1+K_{D\delta}\,\delta^2)$$

$$k = D/mu^2 = K_D\rho d^2/m$$

$R = (D^2+L^2)^{1/2}$. The Magnus force and the yawing force due to yawing are neglected in this formula.

$G = D/\rho d^2u = K_D\ u$ (In most tables, $G = Bu = 5.217 \times 10^{-4} K_D u$)

$i_n = G/G_n$ $(n = 1, 2, \ldots)$

$C_n = m/i_nd^2$ (expressed in lb/in^2 unless otherwise stated)

3. Formulas (Con.)

$$B_n = kC_n$$

$$H = e^{-hy}, \quad h = 0.000{,}045\ m^{-1} = 0.000{,}013{,}716\ ft^{-1}$$

$$\ddot{x} = \frac{-G_n H}{C_n}\dot{x}, \quad \ddot{y} = -\frac{G_n H}{C_n}\dot{y} - g \text{ (standard trajectory)}$$

c. Siacci Functions: Here, c is an arbitrary constant and U an arbitrary value of the velocity u. The formulas are approximately valid if C (lb/in^2) and ρ (ratio to standard) are constant. The subscript $_o$ denotes initial values. (X-113, 114, 276).

$$S = \int_u^U \frac{du}{G}, \quad T = \int_u^U \frac{du}{Gu}, \quad A = \int_u^U \frac{I\,du}{G}, \quad I = c + \int_u^U \frac{2g\,du}{Gu^2}.$$

$$x = \frac{C}{\rho}\cos\theta_o\,(S - S_o)$$

$$t = \frac{C}{\rho}(T - T_o)$$

$$y = x\tan\theta_o - \frac{C^2}{2\rho^2}(A - A_o) + \frac{C\sec\theta_o}{2\rho} I_o x$$

$$\tan\theta = \tan\theta_o - \frac{C\sec\theta_o}{2\rho}(I - I_o)$$

$$\text{If } y = 0, \ \sin 2\theta_o = \frac{C}{\rho}\left[\frac{A - A_o}{S - S_o} - I_o\right]$$

d. Stability. (X-113, 116, 261, 276, 446, 459).

$$N = \nu \sin\delta = D\sin\delta + L\cos\delta \text{ (normal force)}$$

$$K_N = \nu / \rho d^2 u^2 = K_D + K_L$$

$$M = Nd(h - g) = \mu \sin\delta$$

$$K_M = K_N(h - g) = \mu / \rho d^3 u^2$$

$$c^2 = \mu / Bu^2 = K_M \rho d^3 / B$$

$$s = \frac{A^2 N^2}{4B\mu} \quad \text{(Here, N is the spin)}$$

$$\text{If } N = N_o = \frac{2\pi v_o}{nd}, \quad s = \frac{\pi^2 v_o^2 A^2}{\rho n^2 d^5 B K_M u^2}$$

Under standard conditions, $\rho = \rho_o$, $u = v_o$, $s_s = \dfrac{\pi^2 A^2}{\rho_o n^2 d^5 B K_M}$

3. Formulas (Con.)

The following formulas are approximately valid if the yaw is small, say less than 10°. Neglecting the variation of π radians in orientation during each period of yaw, which usually occurs near the minimum yaw:

$$\dot{\phi} = AN/2B, \qquad \phi' = \pi A/Bnd$$

$$T = \pi/\dot{\phi}p, \qquad p = (1 - 1/s)^{1/2}, \qquad L = \pi/\phi' p$$

$$q = \pi/T = AN/2Bp$$

$$s = (T\dot{\phi}/\pi)^2 (s - 1) \qquad s = (L\phi'/\pi)^2 (s - 1)$$

$$s = \frac{(T\dot{\phi}/\pi)^2}{(T\dot{\phi}/\pi)^2 - 1} \qquad s = \frac{(L\phi'/\pi)^2}{(L\phi'/\pi)^2 - 1}$$

$$\epsilon \leq \frac{2d - d_1 - d_2}{2L} \text{ (rad), 1 rad = 57.3 deg = 3438 min}$$

$$\alpha_0 = \left[\frac{2B}{A} - 1\right] \frac{\epsilon}{p}$$

The necessary and sufficient condition for stability is that

$$\frac{1}{s} < \frac{\left[2\,\dfrac{d^2 K_H}{B} - \dfrac{d^2}{A}(K_A - 2K_J)\right]\left[2\,\dfrac{K_L}{m} + \dfrac{d^2}{A}(K_A - 2K_J)\right]}{\left[\dfrac{K_L}{m} + \dfrac{d^2 K_H}{B}\right]^2}.$$

Since the right member of this inequality can never exceed 1, it is necessary, though not sufficient, that $s > 1$ or else negative.

The following empirical formulas give approximate values of the normal force coefficient and the distance from the base to the center of pressure for projectiles with ogival heads:*

$$K_N = 0.020\,a - 0.748\,b + 0.1715\,c + 0.540\,d - 0.0266\,e,$$

$$h = -0.0135\,a + 1.97\,b + 0.6276\,c + 0.4837\,d - 0.0233\,e,$$

where

a is the angle of boat-tail, in degrees,
b is the length of boat-tail, in calibers,
c is the length of the cylindrical part of the body, in calibers,
d is the length of the ogival head, in calibers,
e is the radius of the ogival arc, in calibers.

The following formulas, whose empirical coefficients were poorly determined, pertain to square-based projectiles with conical heads:*

*Some data have been determined recently by free flight in the Aerodynamics Range, but have not yet been published. The above empirical formulas yield approximately the same values for K_N and h when the ogival radius is moderately long, but give different results for conical or nearly conical heads.

3. Formulas (Con.)

$$K_N = 0.575 + 0.25\, j,$$

$$h = c - 0.51 + 0.30\, j,$$

where

c is the length of the cylindrical part of the body, in calibers,
j is the length of the head, in calibers.

e. Drift: (261, 276)

$L = \lambda \sin \delta$ (cross wind force)

$$K_L = \lambda / \rho d^2 u^2$$

$$\kappa = \lambda / mu = K_L \rho d^2 u/m$$

$$c_1 = \lambda / mu^2 = K_L \rho d^2/m$$

$$Q = K_L/K_M u^2$$

$j_r = Q/Q_r$ $(r = 1, 2, \ldots)$ if Q_r is a standard drift function

$$C_{L_r} = n/2\pi gpj_r v_o = md^2 n/2\pi gAj_r v_o$$

$\ddot{z} = \dfrac{NQ\kappa}{N_o C_L} - \dfrac{G\rho \dot{z}}{C}$ (The subscript is dropped from Q, C_L, G and C)

Approximately, on a nearly horizontal trajectory, if $K = K_L/K_M C_L$,

$$\frac{d(\dot{z}/K)}{dx} = \frac{N}{N_o v^2} - \frac{B\rho}{C}(\dot{z}/K), \quad \frac{d(z/K)}{dx} = \frac{\dot{z}/K}{v}$$

Then, since $D = z/x$ (rad),

$\dfrac{D}{K_L} = \dfrac{z/K}{K_M C_L x}$ (whence K_L can be found if D is observed)

The Magnus force,

$$K = \rho u N d^3 K_K \sin \delta = muN\lambda_1 \sin \delta,$$

also has a very small effect on the direction of motion of the center of gravity.

f. Damping: (261, 276, 446, 459)

$w = (\dot{\delta}^2 + \dot{\phi}^2 \sin^2 \delta)^{1/2}$ (angular velocity of axis)

$K_H = H/\rho d^4 u$ (Hw is the yawing moment)

$$f = H/B = K_H \rho d^4 u/B$$

$$K_J = J/\rho d^4 uN \sin \delta$$

$$\gamma = J/AN \sin \delta = K_J \rho d^4 u/A$$

3. Formulas (Con.)

The following formulas are approximately correct along a nearly horizontal trajectory if the initial minimum yaw is zero, the retardation coefficient is constant, the damping factors are proportional to the velocity, and the subscript $_o$ pertains to $x = 0$.

$$s = s_o e^{2kx}, \quad p = (1 - 1/s)^{1/2}, \quad r = \frac{f - \kappa + 2\gamma}{2p}$$

$$\alpha = \alpha_o (p_o/p)^{1/2} \exp\left(-\frac{f + \kappa}{2v} x\right) \cosh\left(\frac{r}{v} x\right),$$

$$-\beta = \alpha_o (p_o/p)^{1/2} \exp\left(-\frac{f + \kappa}{2v} x\right) \sinh\left(\frac{r}{v} x\right).$$

If α_1 and α_2 are the maximum yaws at x_1 and x_2, and $|\beta_2|$ is the minimum yaw at x_2,

$$\left|\frac{r}{v}\right| = \frac{1}{x_2} \tanh^{-1} \left|\beta_2/\alpha_2\right|, \quad \left|\beta_1\right| = \alpha_1 \tanh\left|\frac{r}{v} x_1\right|,$$

$$f - \kappa + 2\gamma = 2pr,$$

$$f + \gamma = \frac{v}{x_2 - x_1} \log_e \frac{p_1 (\alpha_1^2 - \beta_1^2)}{p_2 (\alpha_2^2 - \beta_2^2)}.$$

Usually, but not always, r is approximately 0.

The yawing moment coefficient, determined with projectiles from caliber 0.30 to 37 mm inclusive at velocities from 2000 to 3050 ft/sec, approximately satisfies the relation

$$K_H = 0.35\ L^{1.5}$$

where L is the length of the projectile, expressed in calibers.

g. Aircraft Gunfire Trajectories: (116, 345)

$$u_o^2 = v_o^2 + 2wv_o \sin Z \cos A + w^2$$

$$\delta_o^2 = w^2 (1 - \sin^2 Z \cos^2 A) / u_o^2 \quad \text{(approximately)}$$

$s_o = v^2 s_s / \rho u_o^2$ if s_s is the standard stability factor, and ρ is the ratio of the air density to the standard air density at the surface of the earth

$$c' = \frac{f + \kappa}{2u} = \frac{1}{2} \rho_s d^2 \left[\frac{K_H d^2}{B} + \frac{K_L}{m}\right]$$

$$c'' = K_D \rho_s d^2/2m$$

$$c = c' + \frac{c''}{s_o - 1}$$

3. Formulas (Con.)

$$S = S_o + \frac{\rho}{C} P + \frac{K_D \delta \delta^2_o}{2Cc} \frac{s_o - 1/2}{s_o - 1}(1 - e^{-2 \rho c P})$$

$$\frac{dt}{dp} = \frac{1}{u}$$

$$\frac{d^2Q}{dP^2} = \frac{g}{u2}$$

$$b = \frac{ANK_L}{mdK_M}$$

$$\Delta = b\delta_o/u_o$$

h. Spin: (287, 408)

$$N_o = 2\pi(v_o + v_r - v_b) / nd$$

$v_r = \frac{m+c/2}{R} v_o$ (approximately; here, c is the mass of the propelling charge, and R is the mass of the recoiling parts of the gun)

$$\log_e N = \log_e N_o - \frac{K_A d^4}{A} \int_0^t \rho u \, dt$$

Approximately, on a nearly horizontal trajectory,

$$\log_e N = \log_e N_o - \frac{K_A d^4 \rho}{A} x$$

$$K_A = M_s / \rho d^4 uN$$

$$K_{DF} = D_F / \rho d^2 u^2 \approx 4K_A$$

$$C'_{DF} = D_F / \rho S' u^2 \approx 4K_A d^2/S'$$

The skin friction drag is a function of Reynold s number,

$$R = ud\rho / \sigma .$$

The average empirical value of C'_{DF} for ten projectiles is 0.00168.

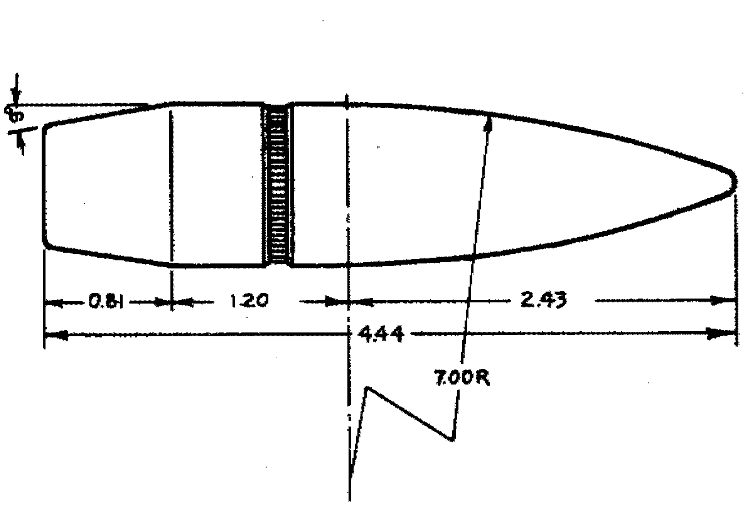
The average value of S'/d^2 for 8 H.E. Shells, excluding the 120 mm Shell M73, is 11.5.

4. Standard Atmospheric Conditions at Surface of Earth

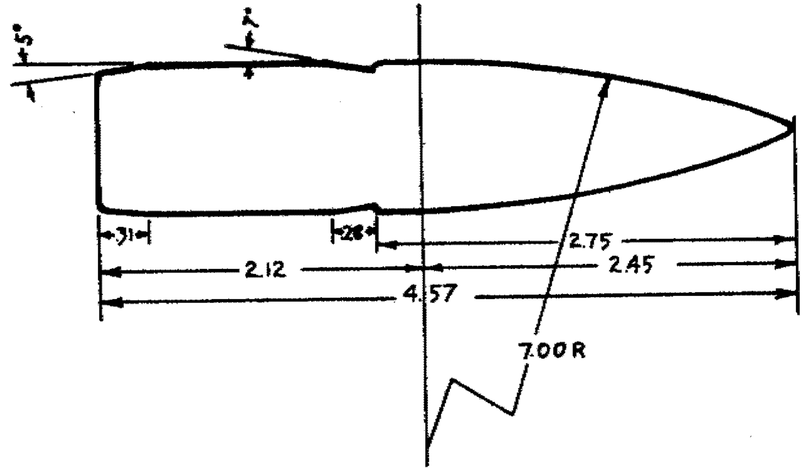
Barometric pressure	750 mm Hg	29.5275 in Hg
Temperature	15° C	59° F
Relative Humidity	78%	78%
Velocity of sound	341.46 m/sec	1120.27 ft/sec

Density	Unit	Log_{10}
1.203,4	kg/m^3	0.08041
0.075,126,5	lb/ft^3	8.87579 - 10
0.000,043,48	lb/in^3	5.63825 - 10
0.000,521,7	$lb/in^2.ft$	6.71743 - 10
0.000,000,301,9	$lb.ft^2/in^5$	3.47989 - 10
525.9	gr/ft^3	2.72089
0.304,34	gr/in^3	9.48335 - 10
3.652	$gr/in^2.ft$	0.56253
43.825	$gr/in.ft^2$	1.64171

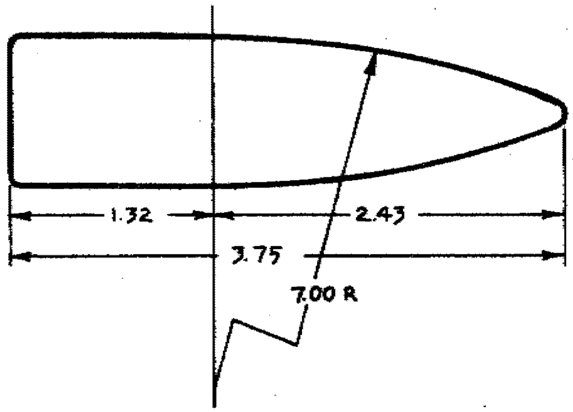
Note: As explained in the introduction, the sketches of the projectiles on the following pages precede the tabular data pertaining to each caliber.



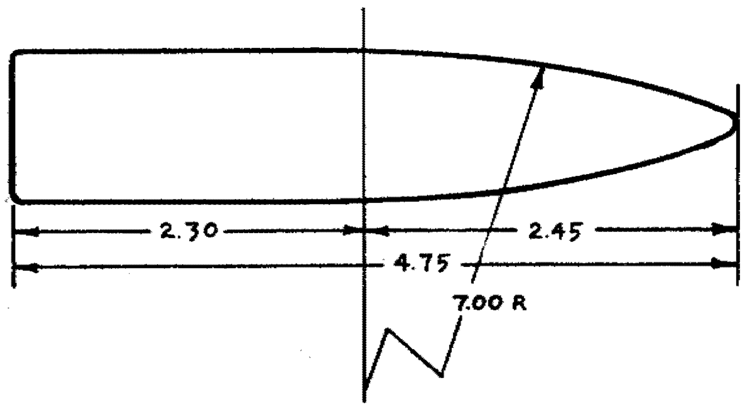
BULLET, BALL, CAL. 0.30, M1



BULLET, A.P., CAL. 0.30, M2

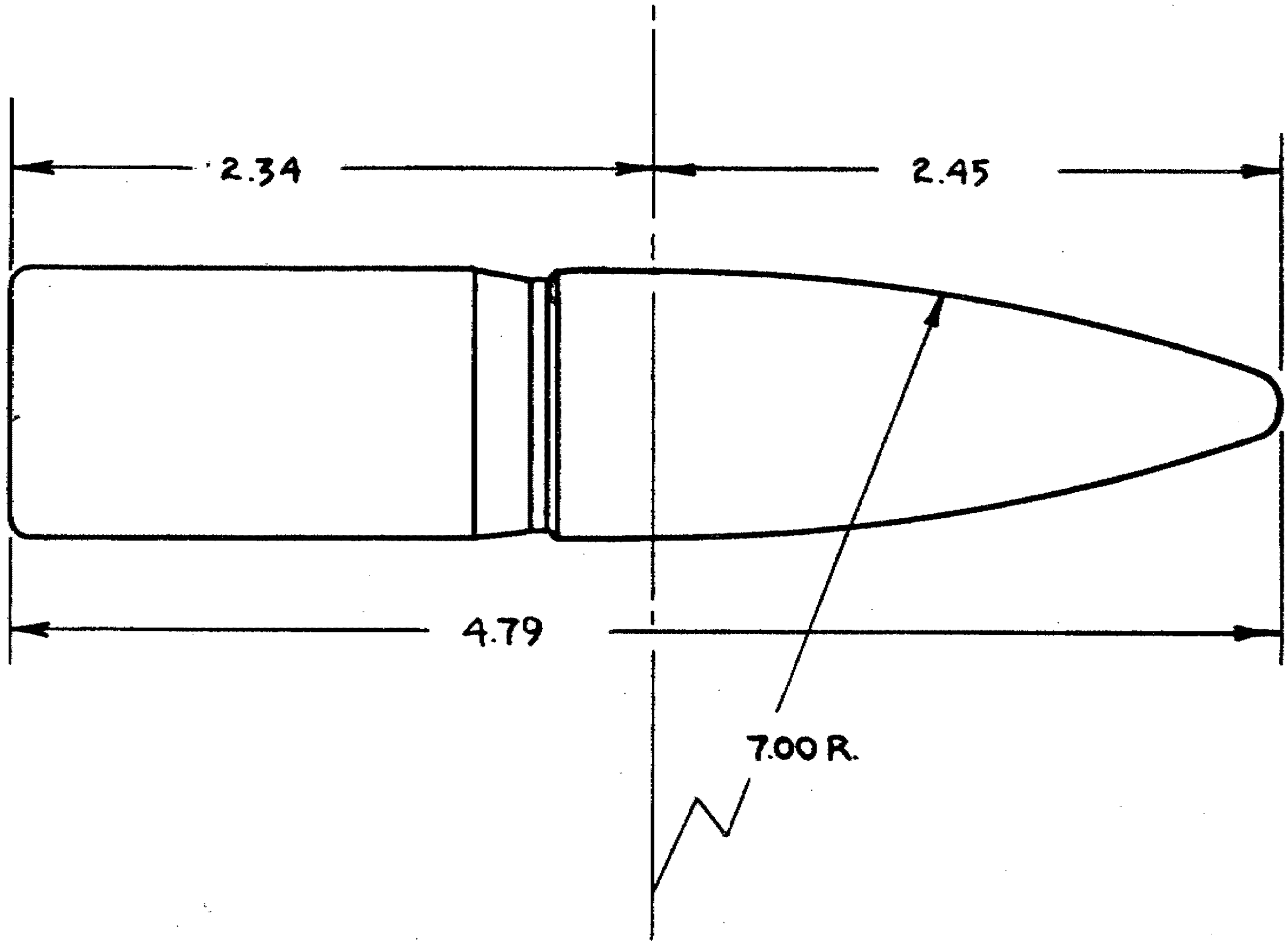


BULLET, BALL, CAL. 0.30, M2



BULLET, TRACER, CAL. 0.30, M1

ALL DIMENSIONS IN CALIBERS



BULLET, A.P.I., CAL. 0.30, T15

ALL DIMENSIONS IN CALIBERS

5. Caliber 0.30 Bullets

a. Physical Characteristics

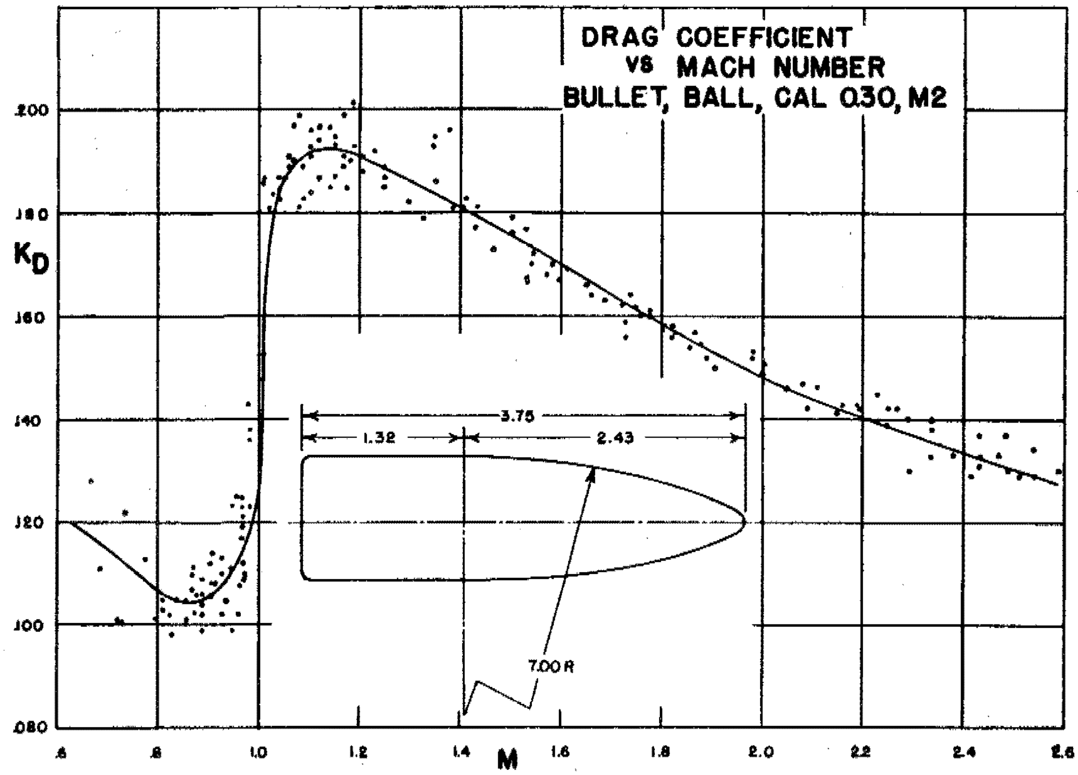
Bullet	Drawing	Weight Grains Std.	Weight Grains Meas.	No. of Rds	g cal.	A gr.in^2	B gr.in^2
Ball M1	B 10986	172	172	5	1.827	1.751	16.40
Ball M2	B 137545	150	151	5	1.455	1.332	12.13
A.P. M2	B 138195	164	167	10	1.980	1.855	20.15
Tracer M1	B 16092	150	149	5	2.097	1.777	18.57
Same w/o Tracer			134	2	2.50	1.557	16.68
Average			142		2.30	1.667	17.60
Night Tracer M25*		150					
Frangible M22 (T44)**		108.5	107	5	1.44	1.043	9.06
A.P.I. T15	B 7638432	157	155	1			

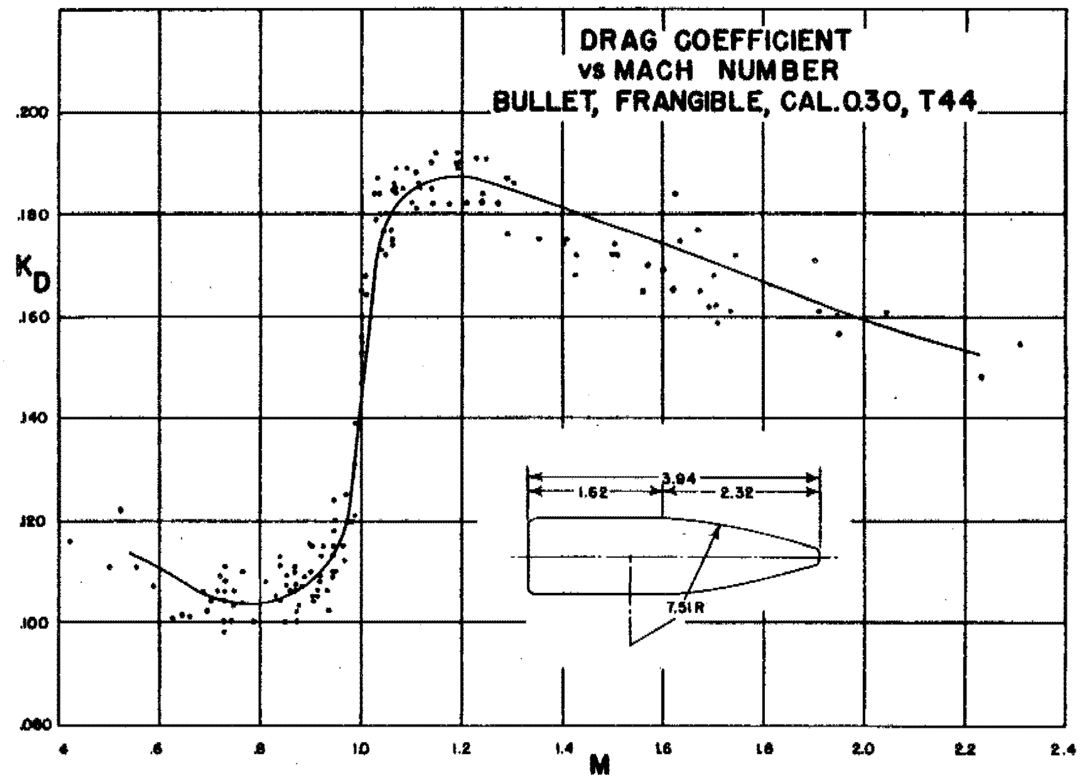
* Same contour as Tracer M1

**Same contour as Ball M2

b. Drag

Bullet	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec	K_D
Ball M1	BRL 276	Range	5	0.77	2600	.107
Ball M2	BRL 276	--	6	1.13	2740	.132
Ball M2		Resist.			see graph	
A.P. M2	BRL 276	Time	5	0.92	2730	.125
Tracer M1	BRL 276	Time & Range	5	0.67	2700	.091
Night Tracer M 25	APG 471.4/490-1	Time	5	0.81	2650	.111
Frangible M22 (T44)	FT 0.30AC-U-1	Time	T44	1.11	1360	.202
Frangible M22 (T44)		Resist.			see graph	
A.P.I. T15	APG 471.4/452	Time	5	1.08	2790	.146


DRAG COEFFICIENT
vs MACH NUMBER
BULLET, BALL, CAL 0.30, M2
K_D
M
3.75
1.32
2.43
7.00 R


DRAG COEFFICIENT
vs MACH NUMBER
BULLET, FRANGIBLE, CAL. 0.30, T44
K_D
M
3.94
1.62
2.32
7.51 R

5. Caliber 0.30 Bullets (Con.)

c. Stability

Pitch of Rifling: 10 inches

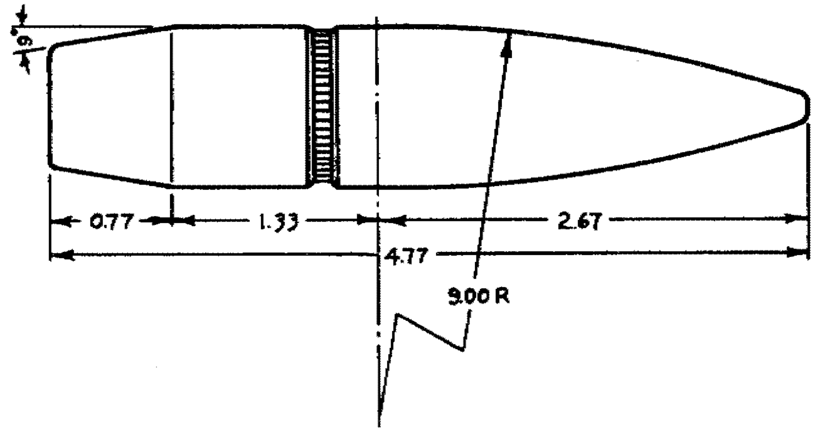
Bullet	Report	No. of Rounds	Velocity ft/sec	Mach No.	S	K_M
Ball M1	BRL 276	5	1990	1.788	1.615	1.24
		7	2672	2.409	1.901	1.05
		6	2892	2.571	2.079	0.96
Ball M2	BRL 276	5	2574		3.42	0.51
A.P. M2	BRL 276	10	2750		1.42	1.36
Tracer M1	BRL 276	10	2528		2.60	0.73*
Night Tracer M25	APG 471.4/490-1		2600		2.52	1.12
Frangible M22 (T44)	FT 0.30AC-U-1		1370		1.61	0.89
Frangible M22 (T44)	APG 471.84/236		1280		2.79[x]	--

* This is an apparent moment coefficient, computed from the observed stability factor and the average values of the moments of inertia of the bullet with and without the tracer composition.

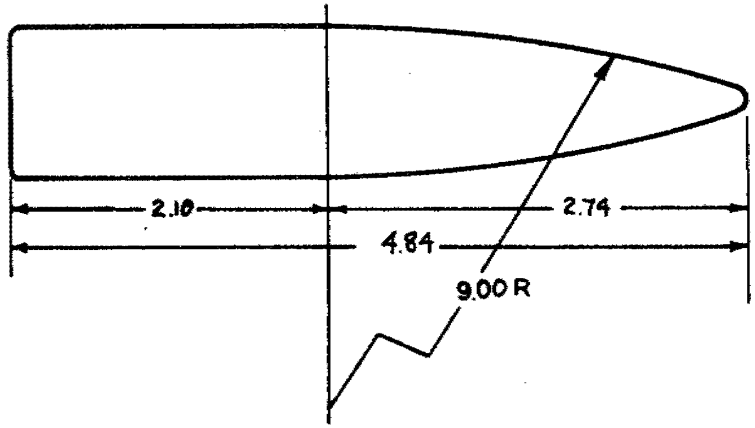
[x] Fired from a special barrel with an 8-inch pitch of rifling.

d. Drift and Damping

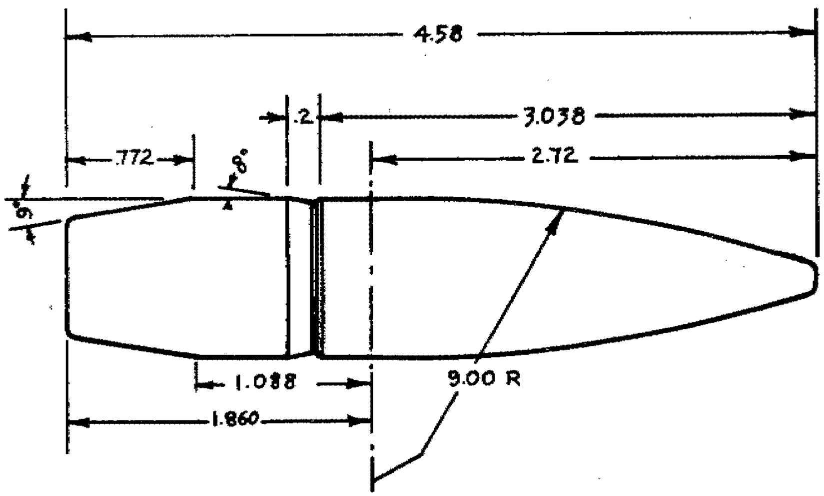
Bullet	Report	Velocity ft/sec	K_L	K_H	K_I
Ball M1	BRL 276 and 357	2656	0.77	3.6	-0.15
Ball M2	BRL 276 and 357	2770	0.98	2.6	-0.09
Tracer M1	BRL 276 and 357	2734	1.07	5.4	-0.22
Frangible M22 (T44)	FT 0.30 AC-U-1	1370	0.98	1.96	-0.06



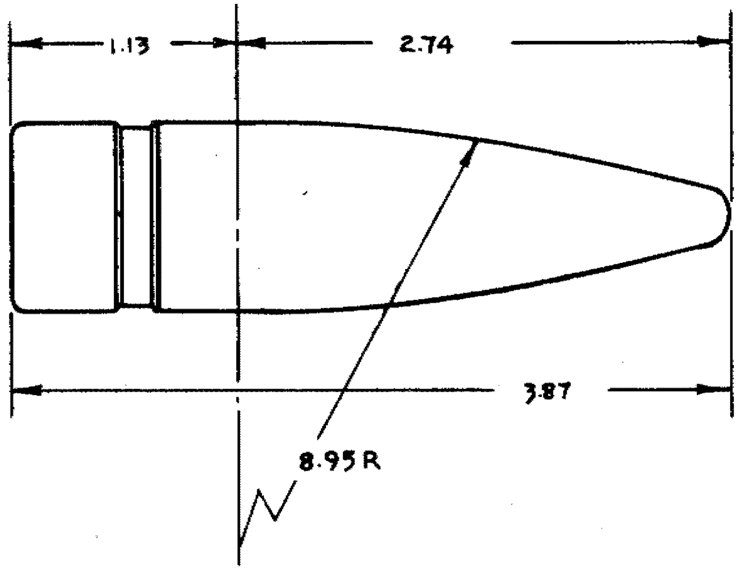
BULLET, BALL, CAL. 0.50, M1



BULLET, TRACER, CAL. 0.50, M1

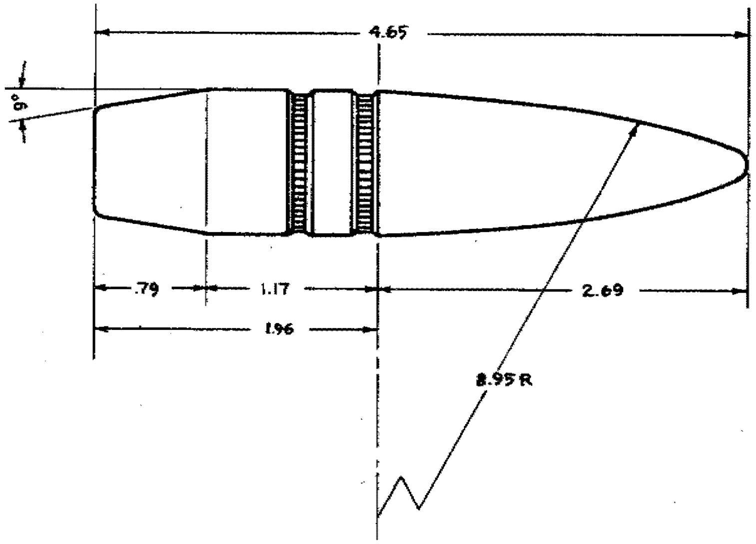


BULLET, A.P., CAL. 0.50, M2

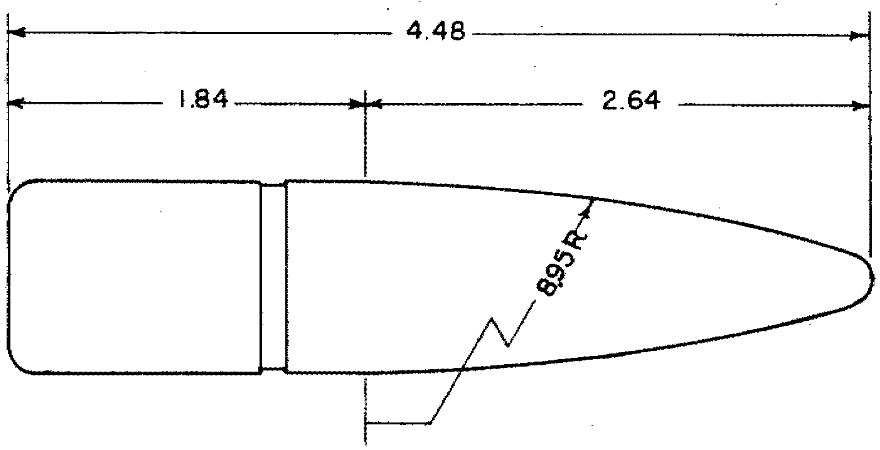


BULLET, A.P.I., CAL. 0.50, T49

ALL DIMENSIONS IN CALIBERS

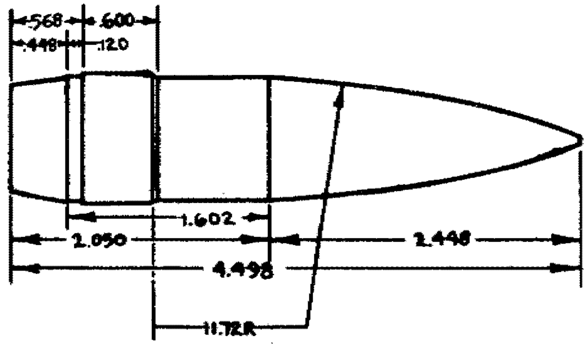


BULLET, INCENDIARY, CAL. .50 M1

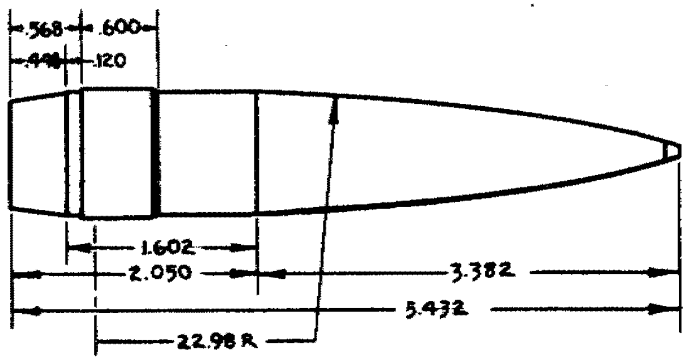


CALIBER .50 BULLET, INCENDIARY M23

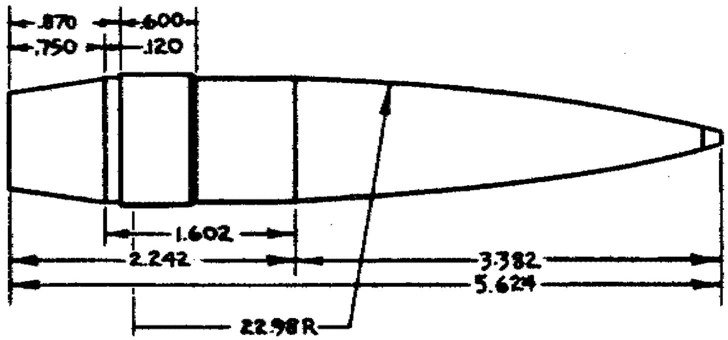
ALL DIMENSIONS IN CALIBERS



CAL. 0.50 MODEL OF 155MM H.E. SHELL M101



CAL. 0.50 MODEL OF 155MM H.E. SHELL P2



CAL. 0.50 MODEL OF 155MM H. E. SHELL P1

6. Caliber 0.50 Bullets

a. Physical Characteristics

BULLET	DRAWING	WEIGHT GRAINS Std.	Meas.	NO. OF RDS.	$\frac{g}{Cal.}$	$\frac{A}{gr.in^2}$	$\frac{B}{gr.in^2}$
Ball M1	B129810	750	741	5	2.043	21.45	244.9
A.P. M2	B137655	710	709	5	1.922	19.71	217.1
Alternate		698	697				
Tracer M1	B129831	674	674	5	2.269	20.94	246.5
Same w/o tracer			602	5	2.402	19.56	211.9
Ave.			638		2.336	20.25	229.2
Alternate		635	641				
Headlight Tracer M21 (T1E1)*			697	3	2.234	22.04	257.1
A.P.I. M8[x]	B7636175	650	653	5	1.823	18.90	179.4
A.P.I., T49	B7640941	501	504	3	1.289	15.28	107.6
A.P.I.T. M20 (T28)		614	613	3	1.738	18.52	167.1
A.P.I.T. T63			513	6	1.618	16.67	114.4
A.P.T. T38			739				
A.P.T. T38E1			670	3	1.991	19.17	217.1
Inc. M1	B174991	625	619				
Inc. M23(T48)	FB19562	512	495	3	1.466	17.89	161.8
Inc. T78			608	3	1.652	19.38	200.6

* Same contour as Tracer M1

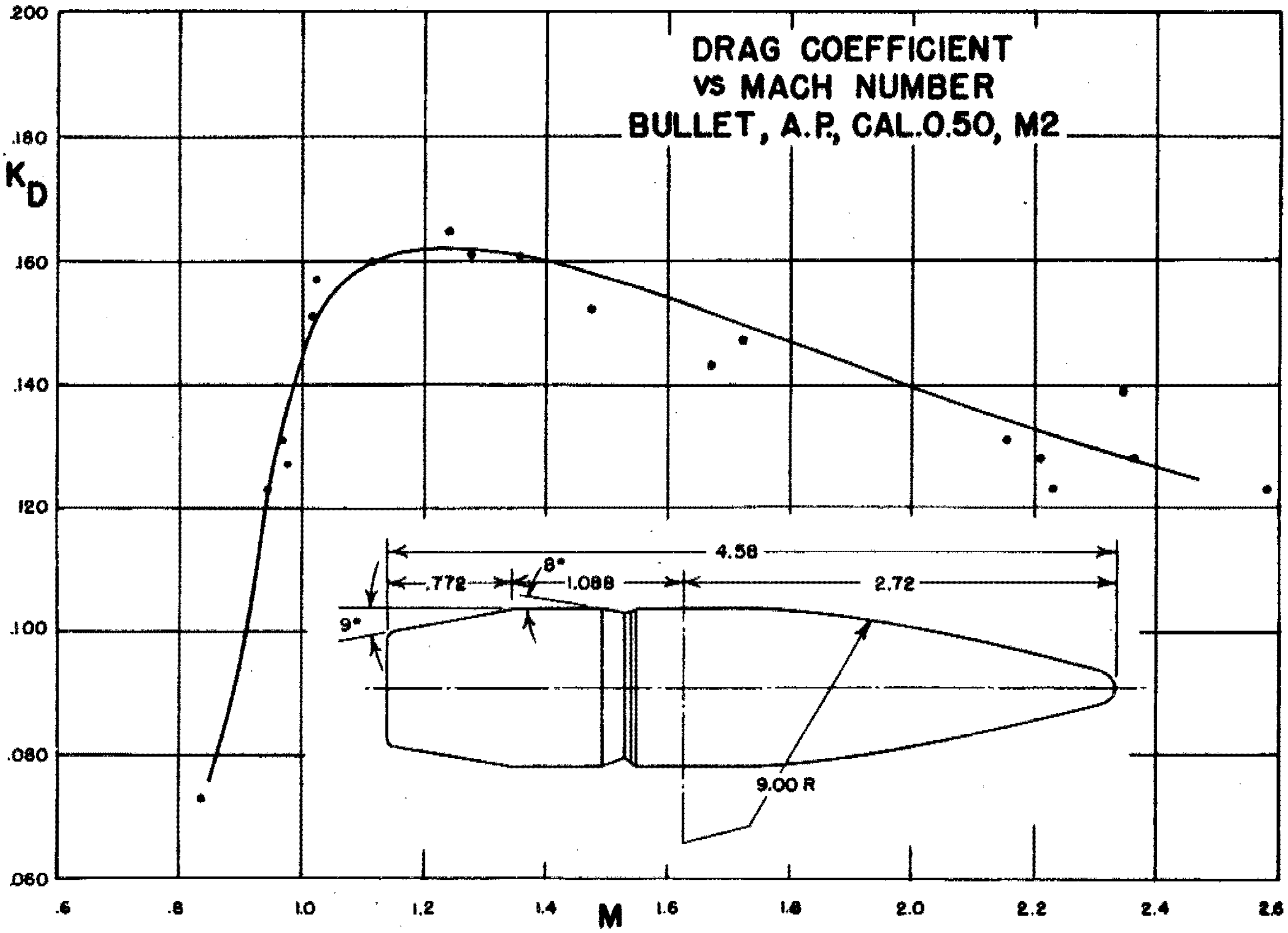
x Same contour as A.P. M2

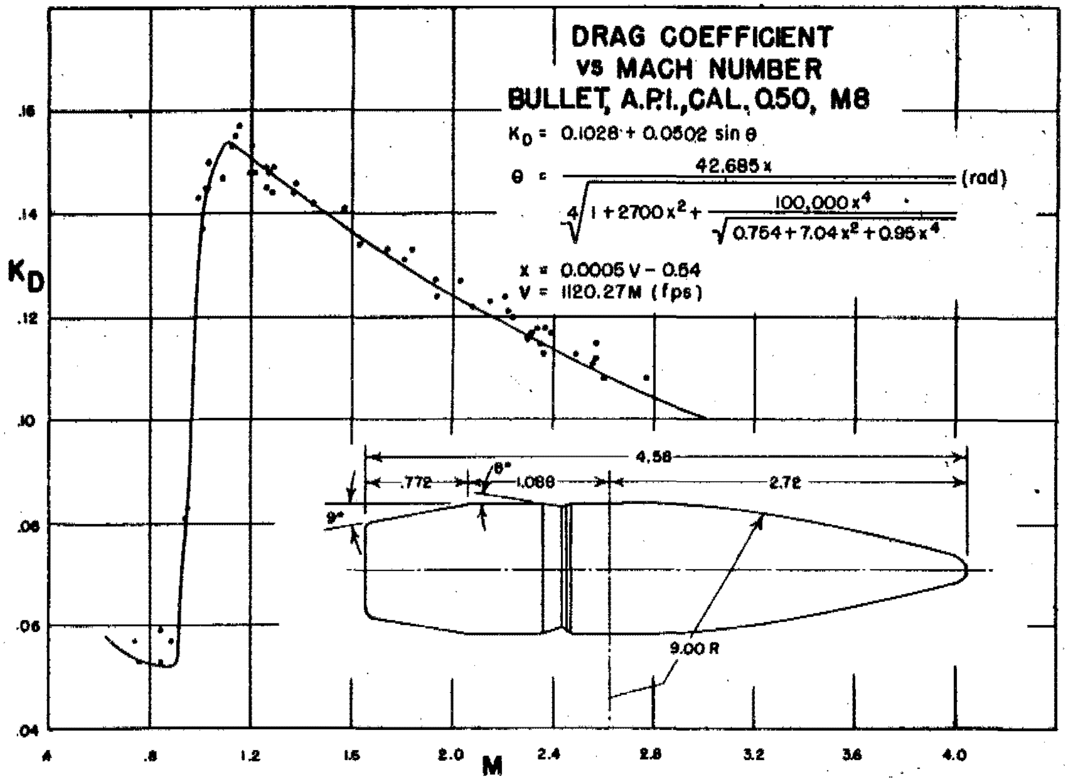
b. Drag

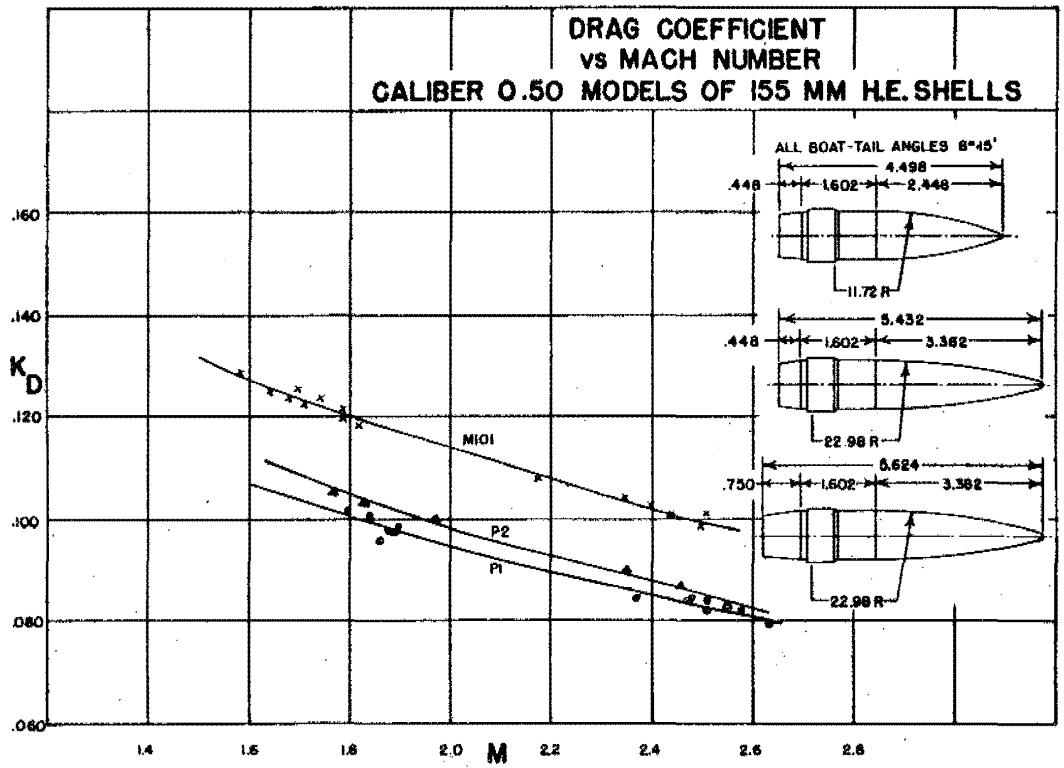
Bullet	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec	K_D
Ball M1	BRL 276	Range and Time	5	0.79	2800	.107
A.P. M2	BRL 276	Time	5	0.86	2900	.115
Alternate	APG 471.4/206	Time	5	0.87	2900	.117
A.P. M2		Resist	See graph			
Tracer M1	BRL 276	Range and Time	5	0.77	2800	.104
Same		Time	5	0.825	2800	.111
Alternate	APG 471.4/206	Time	5	0.81	2800	.109

6. Caliber 0.50 Bullets (Con.)

Bullet	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec	K_D
Models of 155mm HE Shell) M101, P1 & P2)	BRL 567	Resist	See graphs			
Inc. M1	APG 471.4/206	Time	5	0.86	2950	.115
Same		Time	6	0.92	2950	.099
Inc. M23(T48)	K-I-9 Mar 45	Time	7	1.26	3460	.118
A.P.I. M8		Resist	See graph			
A.P.I. T49	K-I-9 Mar 45	Time	7	1.29	3460	.120
Same	APG 471.4/434	Time			4450	.102
A.P.I.T. M20(T28)	APG 471.4/434	Time	5	0.80	2900	.107
A.P.T. T38	APG 471.4/434	Time	5	0.87	2700	.119
A.P.T. T38E1	APG 471.4/434	Time	5	0.81	2900	.109




DRAG COEFFICIENT
VS MACH NUMBER
BULLET, A.P.I., CAL. 0.50, M8
$K_D = 0.1028 + 0.0502 \sin\theta$
$\theta = \dfrac{42.685x}{\sqrt[4]{1 + 2700x^2 + \dfrac{100,000x^4}{\sqrt{0.754 + 7.04x^2 + 0.95x^4}}}}$ (rad)
$x = 0.0005V - 0.54$
$V = 1120.27M$ (fps)
K_D
M
4.58
.772
1.088
2.72
8°
9°
9.00 R


DRAG COEFFICIENT
VS MACH NUMBER
CALIBER 0.50 MODELS OF 155 MM H.E. SHELLS
ALL BOAT-TAIL ANGLES 8°45'
4.498
.448
1.602
2.448
11.72 R
5.432
3.382
22.98 R
5.624
.750
K_D
M
M101
P2
P1

6. Caliber 0.50 Bullets (Con.)

c. Stability - Pitch of Rifling: 15 inches

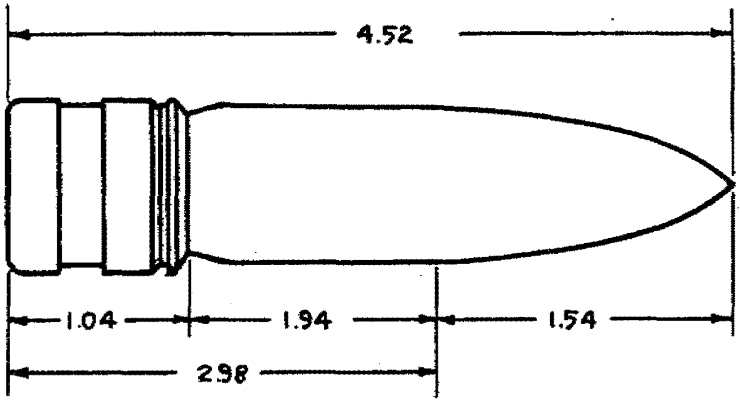
Bullet	Report	No. of Rds.	Velocity ft/sec	Mach No.	s	K_M
Ball M1	BRL 276	4	1982	1.760	1.794	1.15
Ball M1	BRL 276	6	2162	1.960	1.578	1.31
Ball M1	BRL 276	5	2531	2.293	1.603	1.29
Ball M1	BRL 276	4	2929	2.601	1.691	1.22
		Ave.			1.67	1.24
A.P. M2	BRL 276	13	3112	2.72	2.17	0.97
Tracer M1	BRL 276	4	3000	2.62	2.39	0.86*
Headlight Tracer) M21 (T1E1)**)	APG 471.511/1113	5	2700		2.59	0.84
A.P.I. M8	BRL M256	10	2930		1.92	1.20
A.P.I. T49	APG 471.4/398-1	3	3400		2.71	0.95
A.P.I.T. M20(T28)	APG 471.4/434	6	2970		2.05	1.15
A.P.I.T. T63	APG 471.4/376-1	14	3400		2.49	1.10
A.P.T. T38E1	APG 471.4/391-1	8	2890		2.56	0.72
Inc. M23	APG 471.4/365-1	6	3400		1.52	1.50
Incendiary T78	APG 471.4/458-1	6	3000		1.32	1.64

*This is an apparent moment coefficient, computed from the observed stability factor and the average values of the moments of inertia of the bullet with and without the tracer composition.

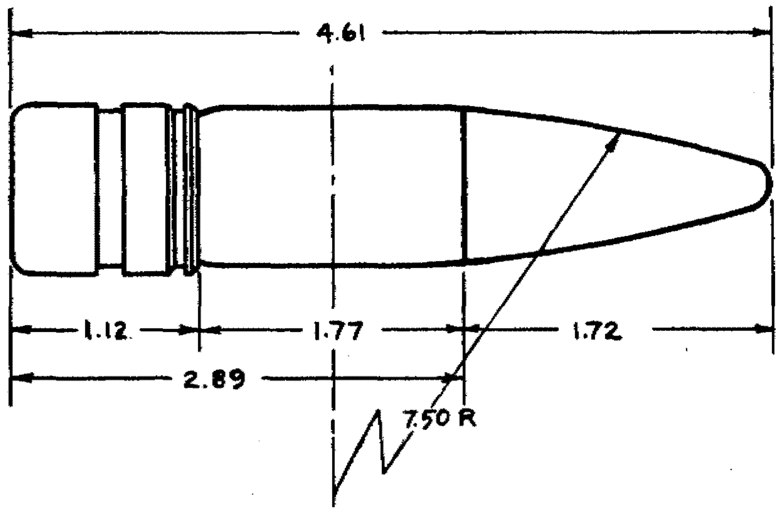
**Same shape as Tracer M1.

d. Drift and Damping

Bullet	Report	Velocity ft/sec	K_L	K_H	K_J
Ball M1	BRL 276 & 357	2540	0.63	6.0	-0.23
A.P. M2	BRL 276 & 357	2655	0.83	3.2	-0.10
A.P.I. M8	BRL M256	2830	1.84	4.8	-0.145
A.P.I. M8	Memo Mar 44	2936	1.15		
Inc. M23	MR	3460	1.44	2.47	-0.036

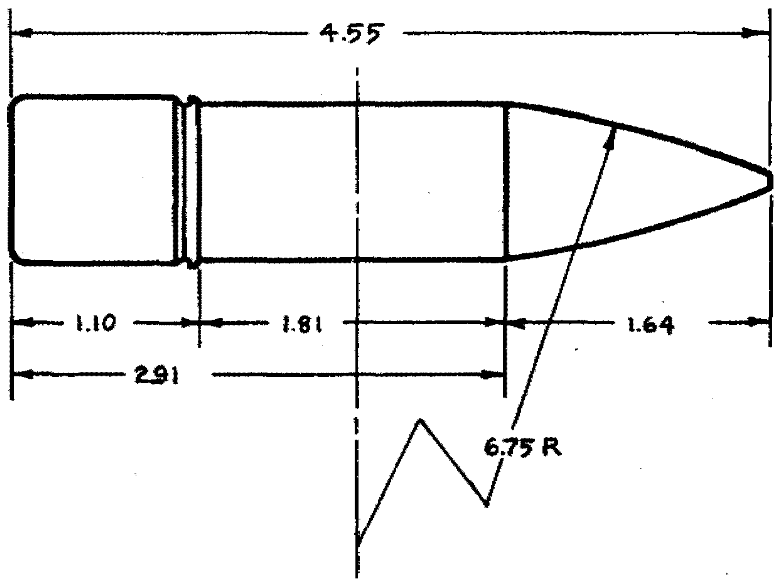


BULLET, A.P., CAL. 0.60, BC-2

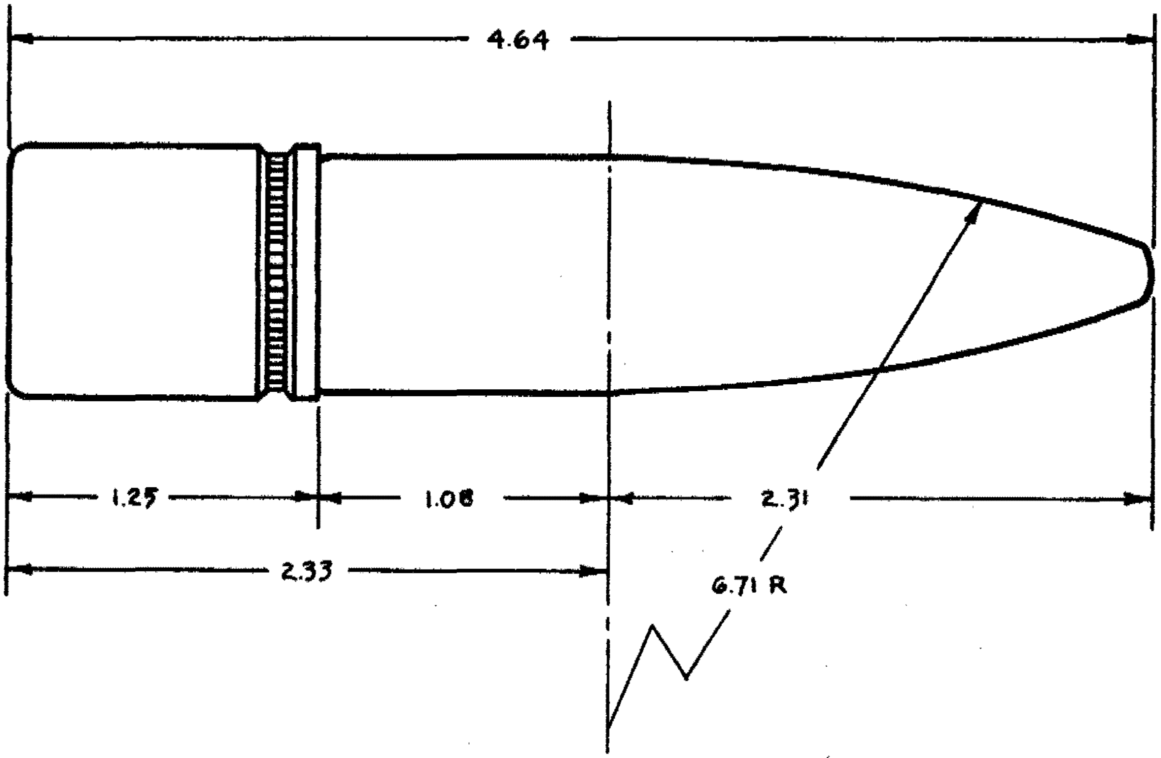


BULLET, A.P., CAL. 0.60, BC-3

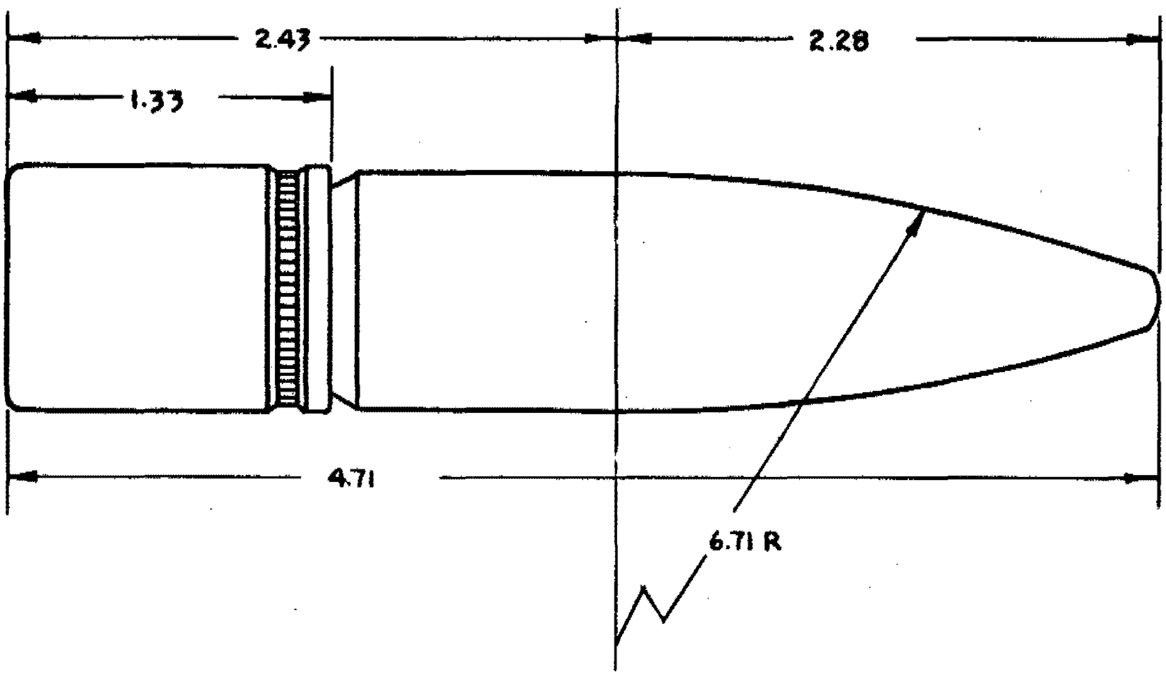
ALL DIMENSIONS IN CALIBERS



BULLET, BALL, CAL. 0.60, T32



BULLET, INCENDIARY, CAL. 0.60, T36, AND T36E2



BULLET, A.P.I., CAL. 0.60, T39

ALL DIMENSIONS IN CALIBERS

7. Caliber 0.60 Bullets

a. Physical Characteristics

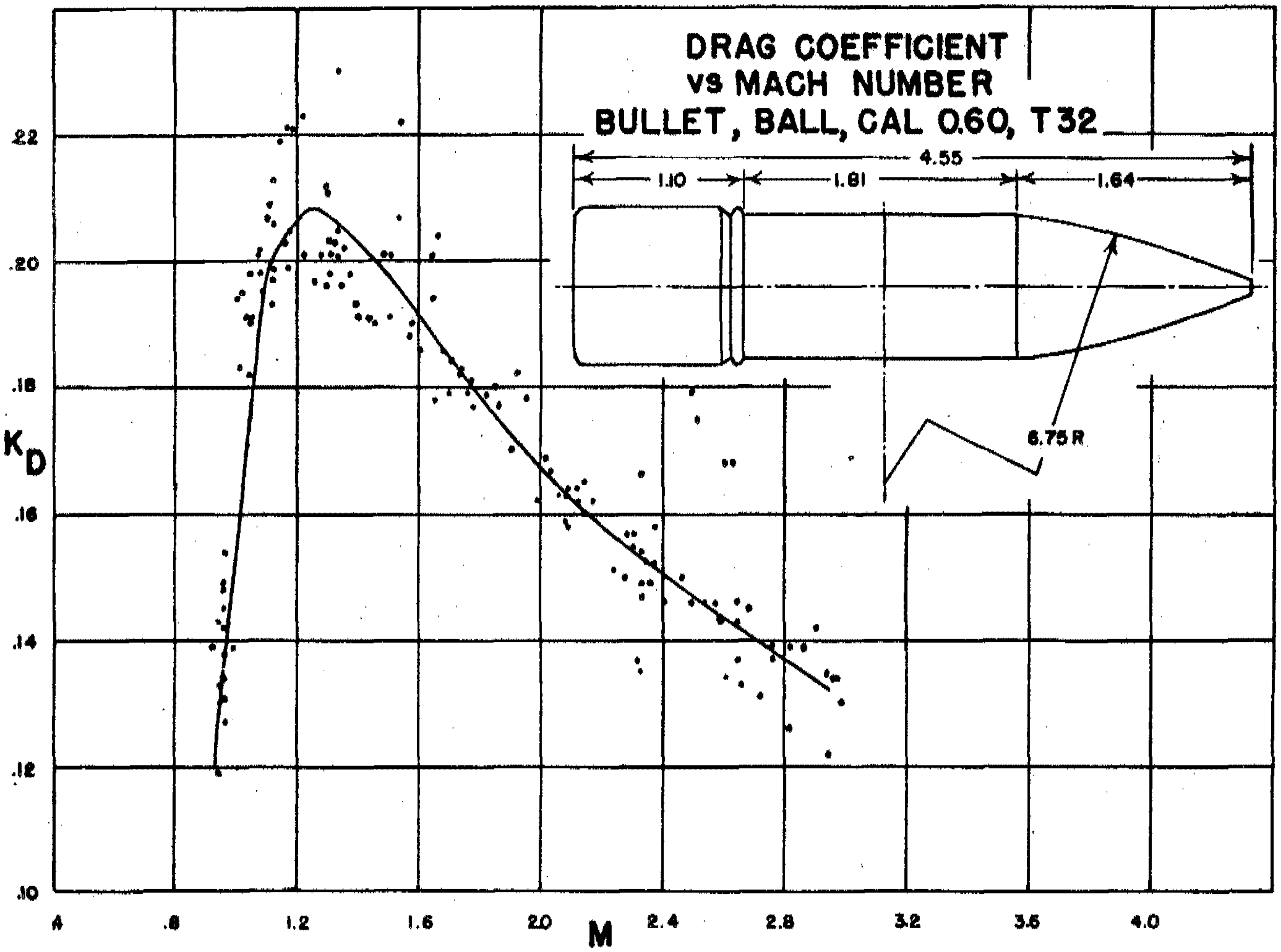
Bullet	Drawing	Weight Grains Std.	Weight Grains Meas.	No. of Rds.	g Cal	A gr.in.^{2}	B gr.in.^{2}
A.P. TS 4	ALX-H 3-2		1234	5	1.838	50.38	607.2
A.P. BC 2	ALX -H 3-42		1192	5	1.867	48.72	554.5
A.P. BC 3	ALX-H 3-188	1180	1209	5	1.938	48.13	619.8
same			1167	2			
Tracer BC 3			1099	1			
H.E. T19			1139	5	1.555	50.15	480.1
Ball T32	B 7637435	1200	1186	5	1.865	49.46	535.0
Ball T32E2		1140	1139	3	1.763	46.9	516.2
Inc. T36*	B 7640421	1140	1146	5	1.554	51.08	506.1
Inc. T36E2		1140	1140	6	1.587	51.18	492.1
Inc. T31		1200	1170	2			
Inc. T41			767	3	1.520	39.61	292.6
A.P.I.T. T60**	B 7641008	1050	1043	3	1.843	46.6	491.4
A.P.I. T39	B 7641005	1140	1138	6	1.765	47.9	490.1

*Formerly called T1E6.
**Same contour as A.P.I. T39.

b. Drag

Bullet	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec	K_D
A.P. BC-3	APG 471.4/180-9A	Photo	7	1.255	3584	.114
Tracer BC-3	APG 471.4/180-9A	Photo	7	1.21	3579	.110
H.E. T19	K-I-9 Mar 45	Time	7	1.14	3545	.104
Ball T32	K-I-9 Mar 45	Time	7	1.25	3550	.114
Ball T32E2	K-I-9 Mar 45	Time	7	1.23	3600	.111
Inc. T36	K-I-9 Mar 45	Time	7	1.29	3550	.118
Inc. T36E2	APG 471.4/478	Time	7	1.29	3550	.118
Inc. T31	APG 471.4/180-9A	Photo	7	1.18	3590	.107
A.P.I.T. T60	K-I-9 Mar 45	Time	7	1.16	3570	.106
A.P.I. T39	K-I-9 Mar 45	Time	7	1.26	3550	.115

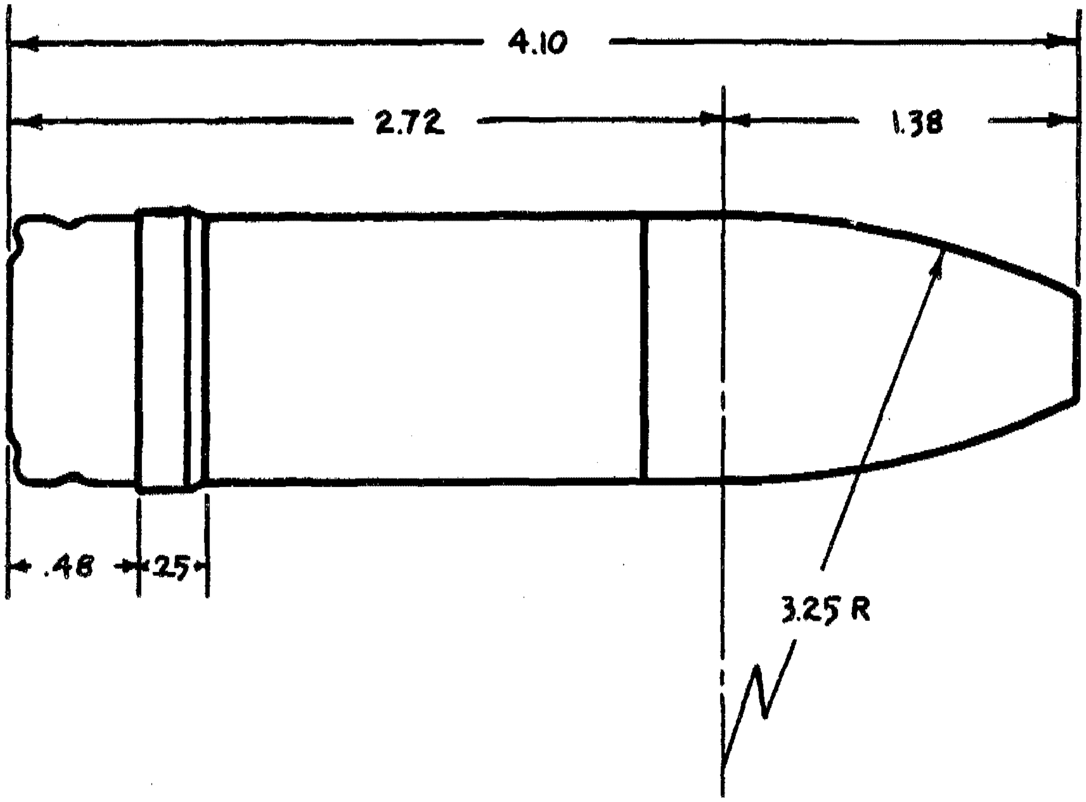
7. Caliber 0.60 Bullets (Con.)



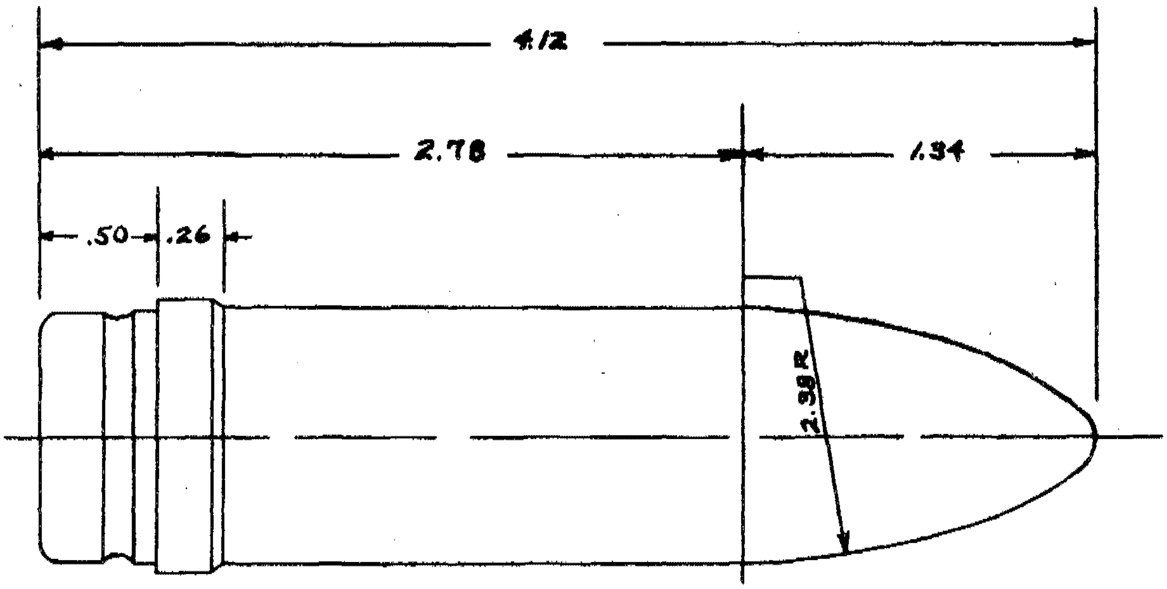
c. Stability

Pitch of Rifling: 18 inches

Bullet	Report	No. of Rounds	Velocity ft/sec.	S	K_M
A.P. TS4	BRL 257	6	3100	1.85	1.03
A.P. BC-2	BRLM 245	9	3520	1.69	1.18
H.E. T19	BRLM 366	8	3500	1.84	1.32
Ball T32	BRLM 305	4	3500	1.85	1.145
Ball T32E2	BRLM 366	6	3600	1.69	1.17
Inc. T36	BRLM 305	6	3600	1.51	1.58
Inc. T36	BRLM 366	6	3450	1.74	1.35
Inc. T36E2	APG 471.4/478		3600	1.53	1.59
Inc. T41	APG 471.4/6-1	3	4200	1.92	1.37
A.P.I.T. T60	BRLM 366	6	3550	2.10	1.08
A.P.I. T39	BRLM 366	11	3550	1.79	1.215

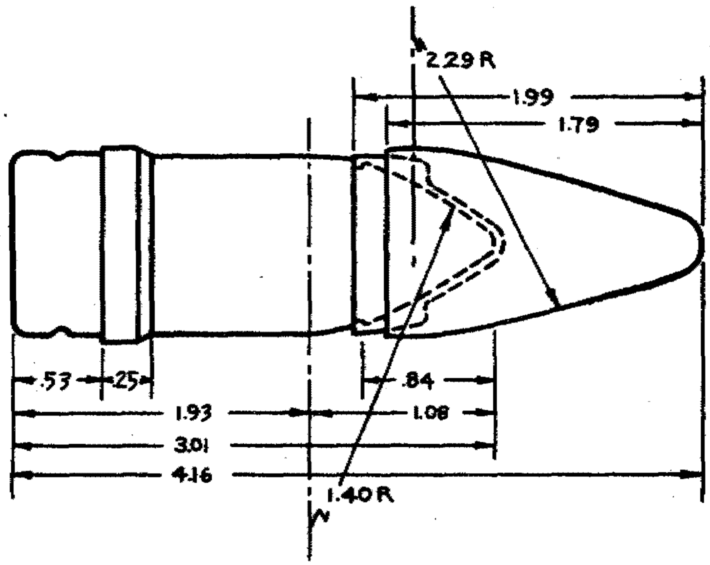


PROJECTILE, BALL, 20MM HISPANO GUN /A/.

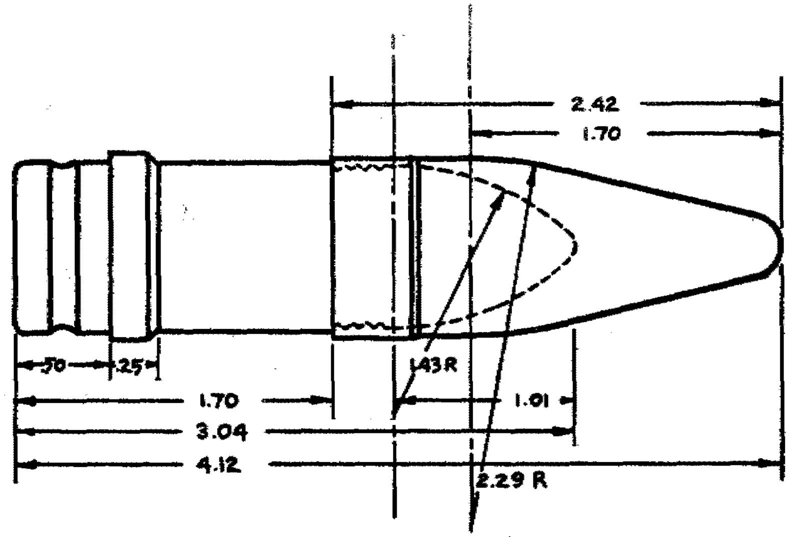


SHOT, A.P., 20MM, M75

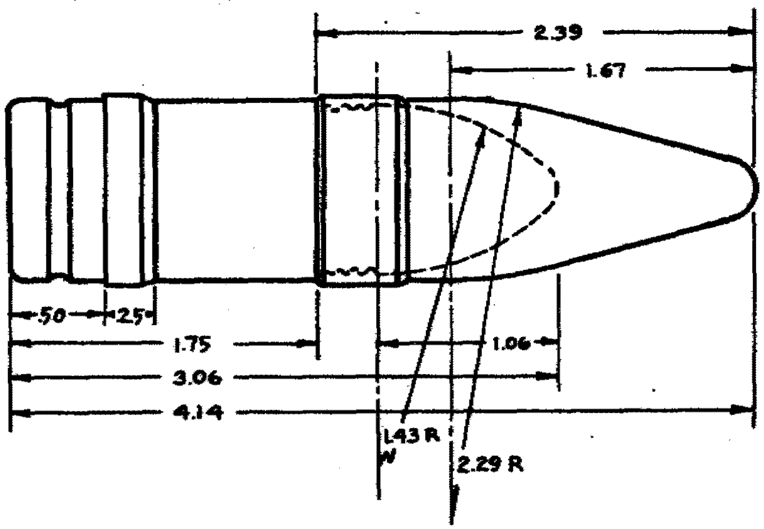
ALL DIMENSIONS IN CALIBERS



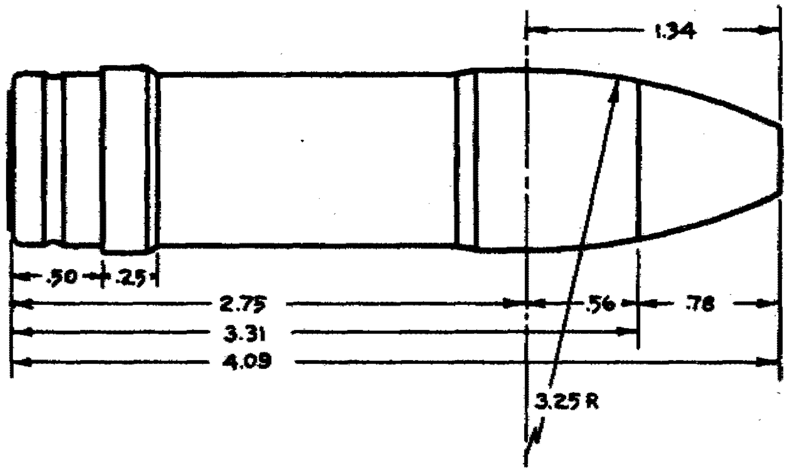
SHOT, A.P., 20MM, T9E4



SHOT, A.P.I., 20MM, T21

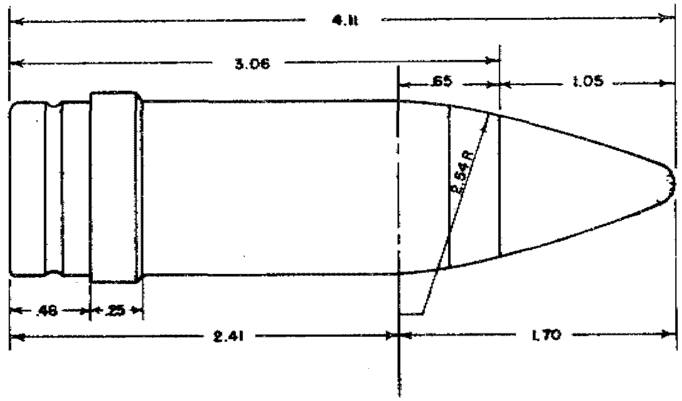


SHOT, A.P., 20MM, M95

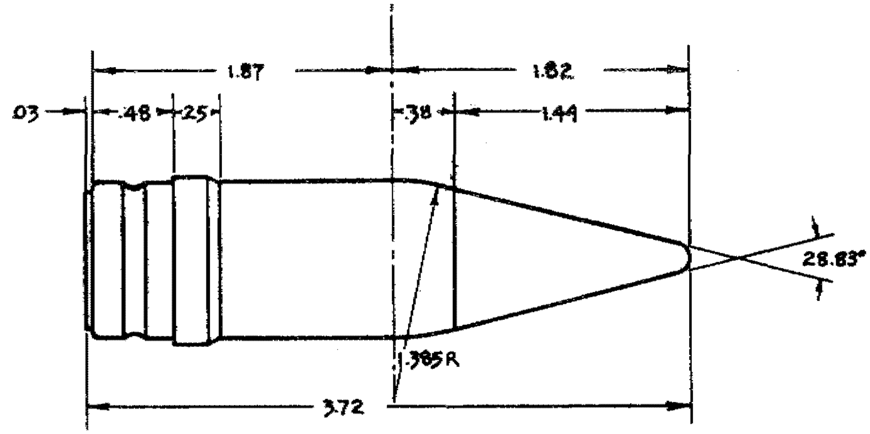


SHELL, H.E.I., 20MM, MARK I;
FUZE, PERCUSSION, D.A., NO. 253, MARK I /A/

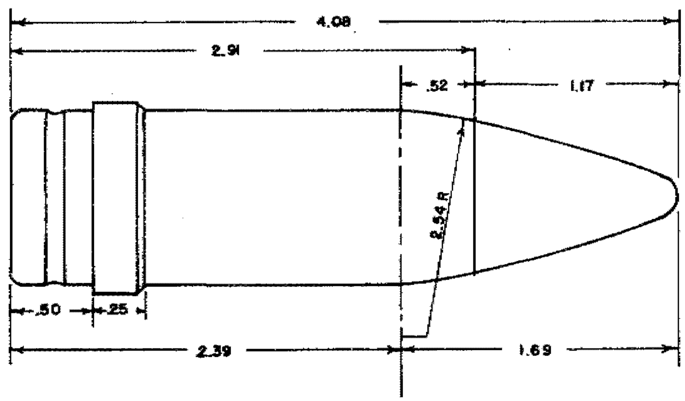
ALL DIMENSIONS IN CALIBERS



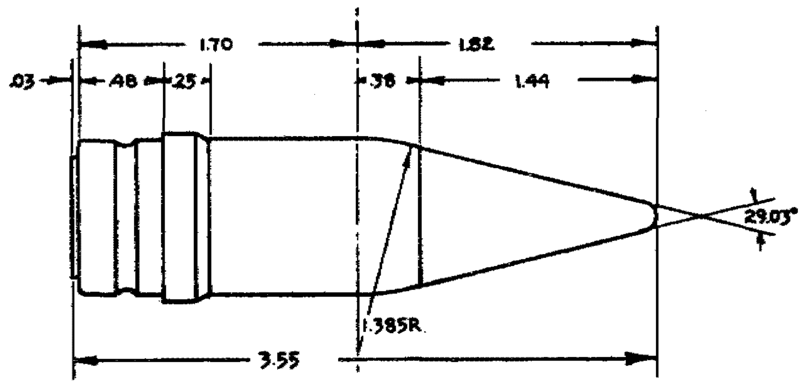
SHELL, H.E.I., 20MM, M97 (T23) FUZE, P.D., M75



SHELL, INCENDIARY, 20MM, T28



SHELL, INCENDIARY, 20MM, M96 (T18)



SHELL, INCENDIARY, 20MM, T35

ALL DIMENSIONS IN CALIBERS

8. 20mm Projectiles

a. Drawings:

Projectile, Ball, Hispano Gun /A/	75-2-299
Projectile, Ball, T4 (same contour as A.P. M75)	
Shot, Armor-piercing, M75	75-2-308
Shot, Armor-piercing, T9E4	TAM 130
Shot, Armor-piercing, M95 (T9E5)	75-2-333 and 341
Shot, Armor-piercing Incendiary, T21	TAM 460
Shell, High Explosive Incendiary, Mark 1	75-2-300
Shell, High Explosive Incendiary, T16 (same contour as H.E.I. M97)	TAM 22 and 463
Shell, High Explosive, T23 (same contour as H.E.I. M97)	TAM 371
Shell, High Explosive Incendiary, M97	75-2-335
Shell, Incendiary, M96 (T18)	75-2-342 and 334
Shell, Incendiary, T28	TAM 1824
Shell, Incendiary, T35	TAM 1979
Projectile, Practice, M99 (T24) (same contour as Incendiary M96)	75-2-343
Fuze, Percussion, D.A., No. 253, Mark I /A/	73-1-178
Fuze, Point Detonating, M75 (T71E4)	TAM 601

b. Physical Characteristics

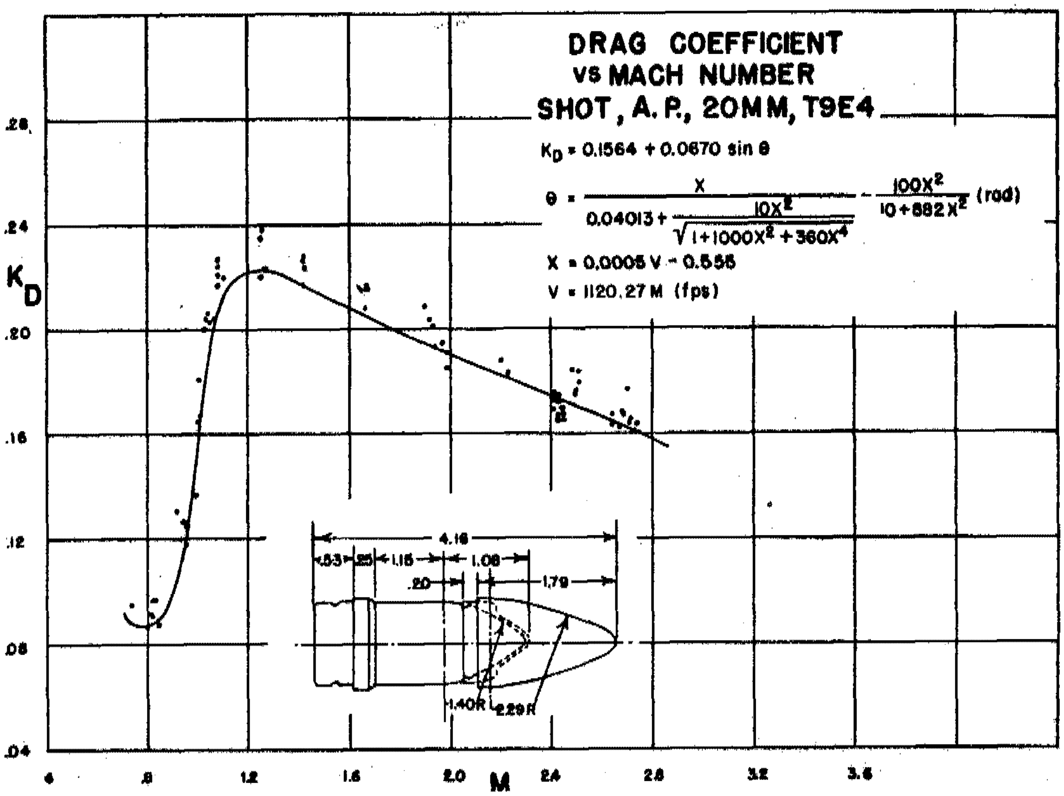
Projectile	Fuze	Weight Grains Std.	Weight Grains Meas.	No. of Rounds	g cal	A $gr.in.^2$	B $gr.in.^2$
Ball (formerly 1935 gr.)		2000					
Ball T4	Plug		2526	5	1.884	190.2	1767
Ball T4	None		2512	5	1.892	190.0	1758
Ball T4	Tracer	2542	2547	5	1.806	190.0	1796
A.P. M75	Tracer	2548					
A.P. T9E4	Tracer	2000	2000	5	1.474	154.5	957
A.P. M95	Tracer	2000					
A.P. M95	wo/tr		1967	3	1.488	148.8	956
A.P.I. T21	Tracer	2000					
A.P.I. T21	None		1980	7	1.536	150.2	1065
H.E.I. Mk 1	Perc.	2030	1995	5	1.860	184.3	1662
H.E.I. T16 (with tracer)	Dummy M75	1900	1955	5	1.719	151.9	1470
H.E. T23	T71E4	2000	2004	5	1.643	165.6	1442

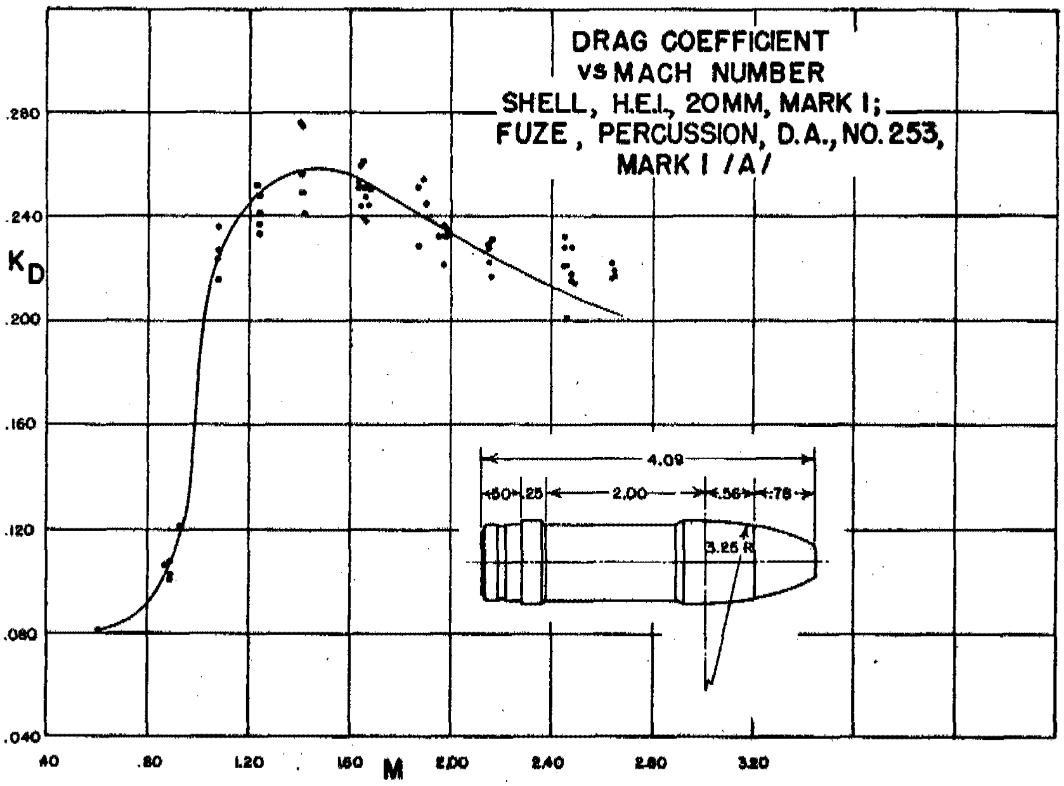
8. **20mm Projectiles (Con.)**

Projectile	Fuze	Weight Grains Std.	Weight Grains Meas.	No. of Rounds	g cal	A $gr.in.^2$	B $gr.in.^2$
H.E.I. M97	M75	2039					
Inc. T35	--	1200	1186	3	1.074	102.2	415.4
Inc. T28	--	1500	1434	3	1.266	125.0	668.7
Inc. M96	--	1920	1993	5	1.553	155.5	1305
Prac. M99	--	2000	1965	5	1.546	163.1	1388

c. Drag.

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
Ball, 1935 gr.	Tracer	BRL 284	Resist	1	0.98	2820	.207
Ball, T4	Tracer	BRL 515	Time	1	0.96	2530	.212
A.P. M75	Tracer	BRL 515	Range	6	1.71	2550	.214
A.P. M75	Tracer	BRL 515	Time	6	1.98	2450	.256
A.P. T9E4	Tracer		Resist		see graph		
A.P. M95	Tracer	BRL 515	Time	5	1.12	3000	.149
A.P. M95	w/o tr	K-I 9 Oct 44	Time	5	1.15	3000	.153
H.E.I. Mk 1	Perc		Resist		see graph		
H.E.I. T16 (with tracer)	Dummy M75	BRL 515	Time	5	1.09	2750	.148
H.E. T23	T71E4	BRL 515	Time	5	1.14	2800	.155
Inc. M96	---	BRL 515	Time	5	1.16	2750	.157
Inc. T28	---	APG 472.5/317-1846	Range	8	1.28 1.28	3200 2700	.127 .145
Inc. T35		APG 471/6-8	Range	8	1.26 1.26	3650 2700	.113 .162
A.P.I. T21	w/o tr	APG 472.5/317-1781	Time	5	1.19	2700	.162


DRAG COEFFICIENT
VS MACH NUMBER
SHOT, A. P., 20MM, T9E4
$K_D = 0.1564 + 0.0670 \sin\theta$
$\theta = \frac{X}{0.04013 + \frac{10X^2}{\sqrt{1+1000X^2+360X^4}}} - \frac{100X^2}{10+882X^2}$ (rad)
$X = 0.0005V - 0.555$
$V = 1120.27M$ (fps)
K_D
M
4.16
.53
.25
1.15
1.08
.20
1.79
1.40R
2.29R


DRAG COEFFICIENT
VS MACH NUMBER
SHELL, H.E.I., 20MM, MARK I;
FUZE, PERCUSSION, D.A., NO. 253,
MARK I /A/
K_D
M
4.09
.50
.25
2.00
.56
.78
3.25 R

8. 20mm Projectiles (Con.)

d. Stability

Pitch of Rifling: 25.586 Cal. (Angle 7°)

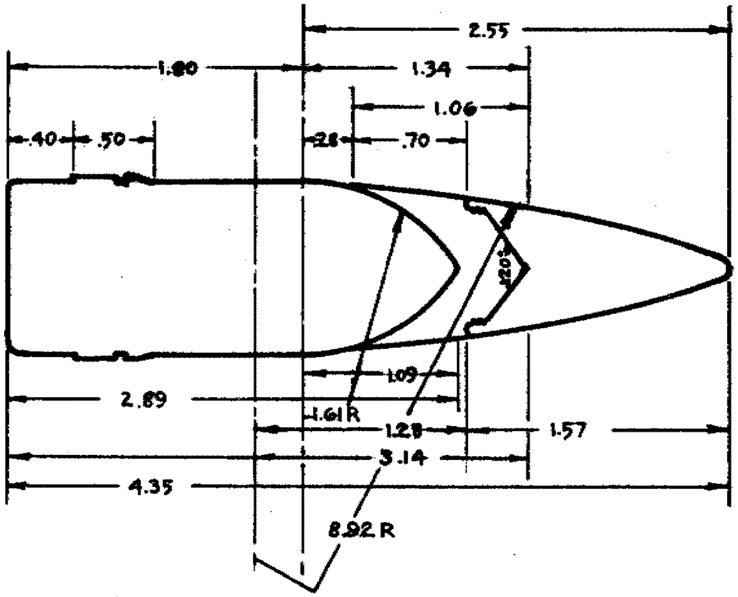
Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	s	K_M
Ball T4	Tracer	BRL 515	4	2530	2.89	1.14
A.P. T9E4	Tracer	BRL 515	12	2750	2.78	1.47
A.P. T95 (M95)	wo/tr	APG 472.5/317-1821	6	2700	2.28	1.68
A.P.I. T21	w/o tr	APG 472.5/317-1821	6	2700	2.52	1.39
H.E.I. Mk 1	Perc	BRL 515	7	2750	2.88	1.16
H.E.I. T16 (with tracer)	Dummy M75	BRL 515	10	2750	2.91	0.89
H.E. T23	T71E4	BRL 515	9	2800	2.85	1.09
Inc. M96	--	BRL 515	8	2750	2.80	1.09
Inc. T28	--	APG 472.5/317-1846		3000	3.07	
Inc. T35	--	APG 471/6-8	3	2600	2.4	
Prac. M99	--	BRL 515	6	2750	2.61	1.20

The caliber of the 20mm gun is 0.787 inches

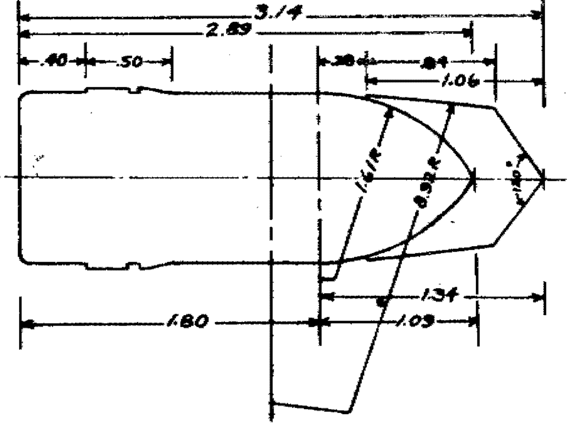
e. Drift and Damping

Projectile	Fuze	Report	Velocity ft/sec.	K_L	K_H	K_J
Ball T4	none	BRL 515	2483	2.50*	4.8	-.10
Ball T4	Tracer	BRL 515	2483	2.50*	2.7	+.02
A.P. M75	Tracer	BRL 515	2530	2.50*		
H.E.I. Mk 1	Perc.	BRL 515	2830	1.12	3.7	-.12
H.E. T23	T71E4	BRL 515	2800	1.27	1.56	-.005

*This value was determined with the A.P. Shot M75 and assumed to be the same for the Ball Projectile T4; but it is probably too high.

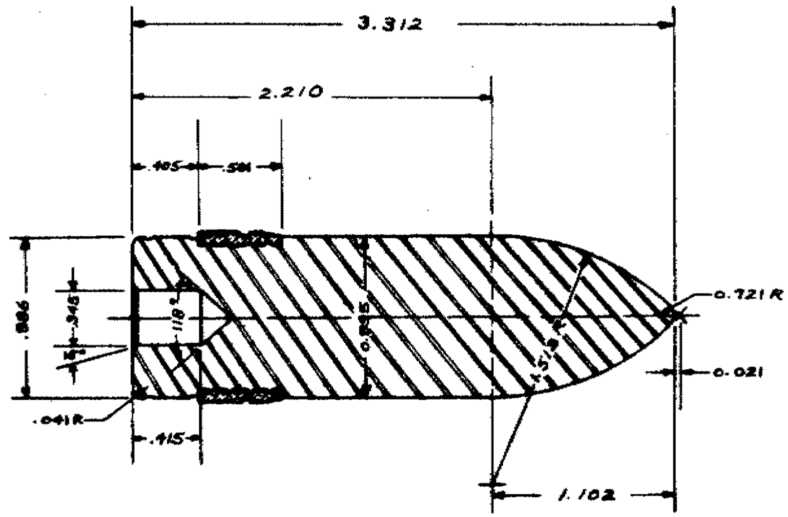


SHOT, A.P.C., 37MM, M51

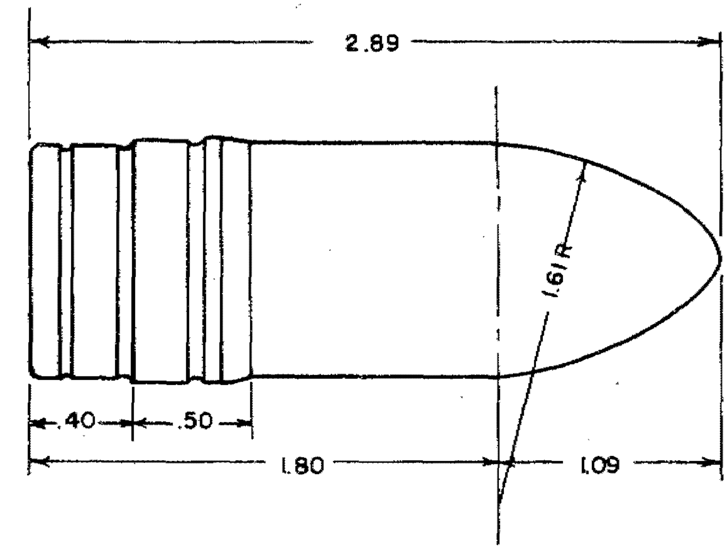


37MM SHOT, A.P.C., M59

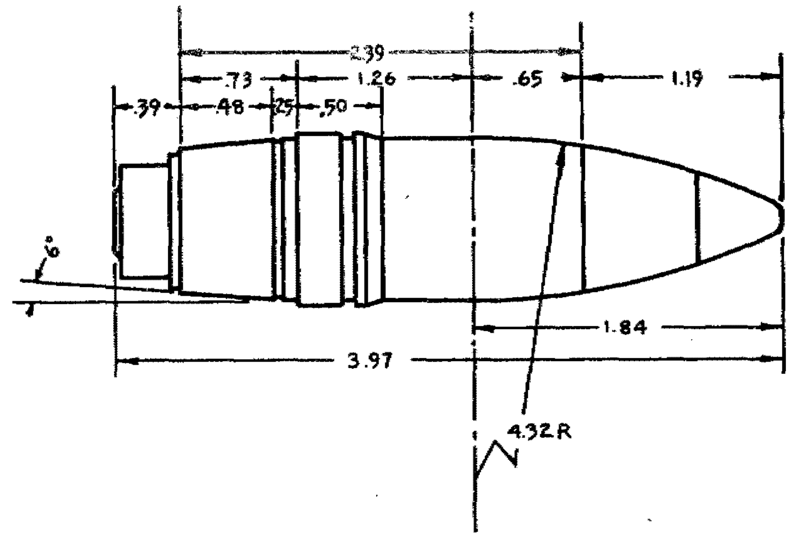
ALL DIMENSIONS IN CALIBERS



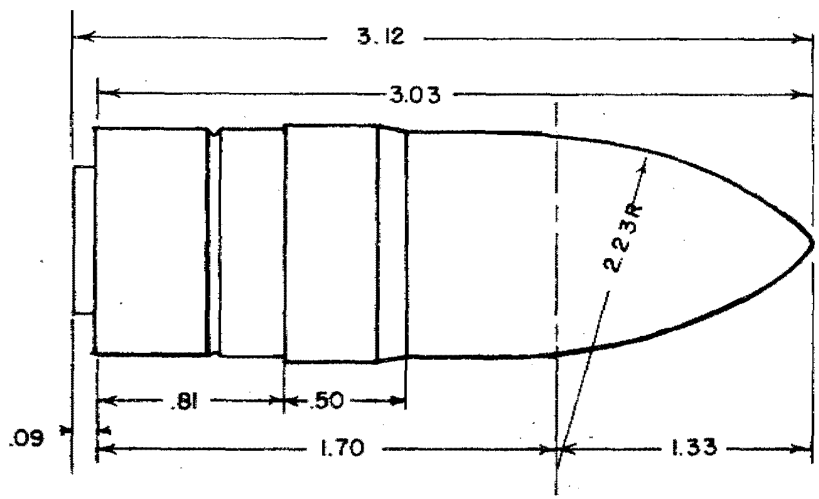
SHOT, A.P., 37MM, M74



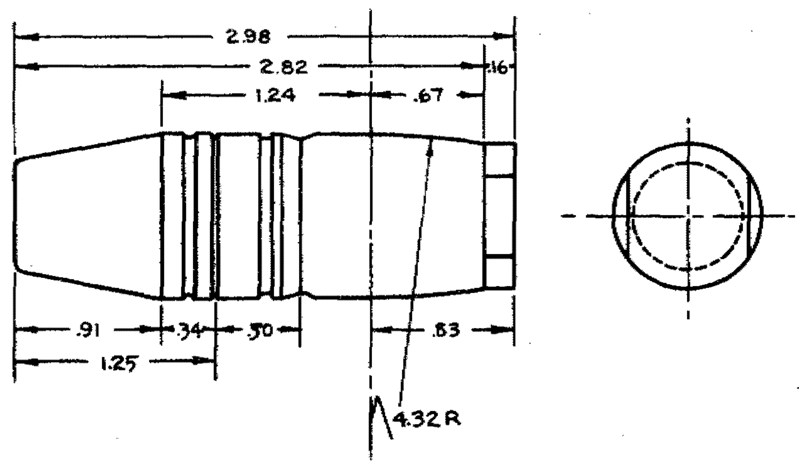
SHOT, A.P., 37MM, M80



SHELL, H.E., 37MM, T2; TRACER, RED, M2; FUZE, DUMMY, T30.

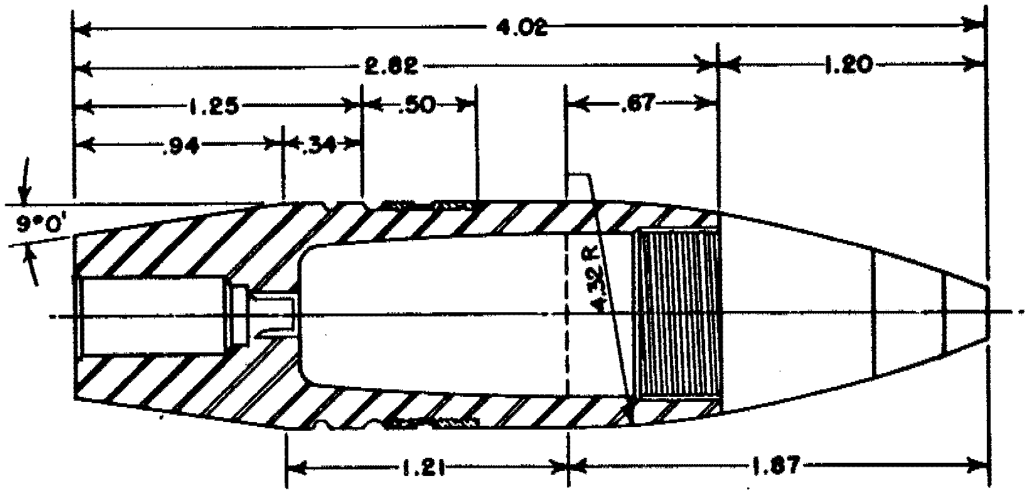


SHELL, 37MM, H.E. MARK 2;FUZE, B.D. M38A1

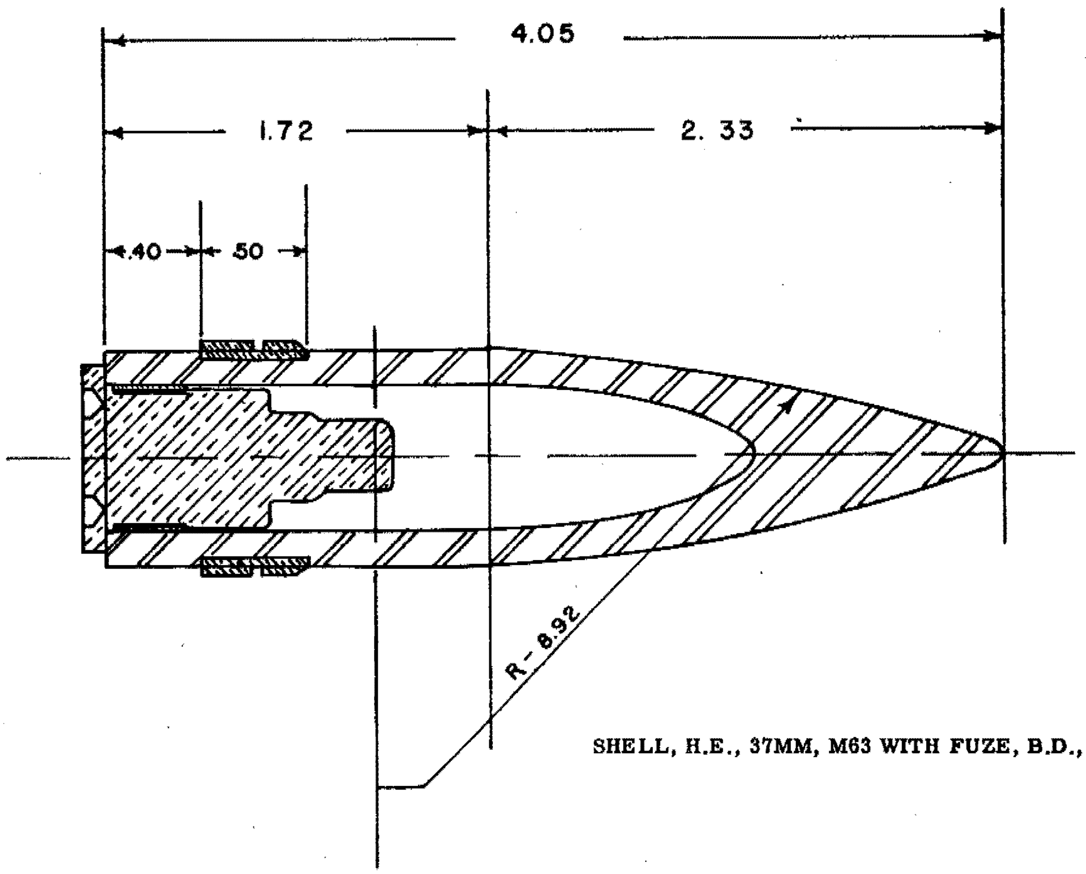


SHELL, PRACTICE, 37MM, M55A1; PLUG, CLOSING, 75-14-309A.

ALL DIMENSIONS IN CALIBERS

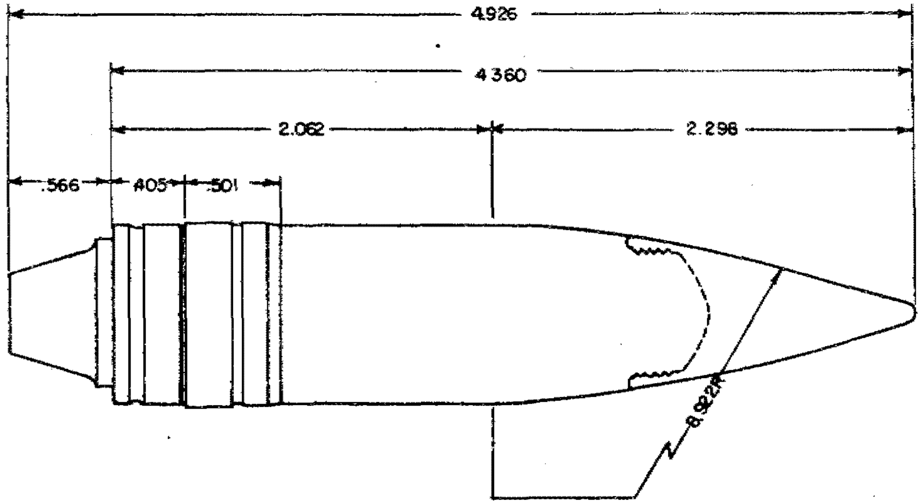


SHELL, 37MM, H.E., M54; FUZE, P.D., M56

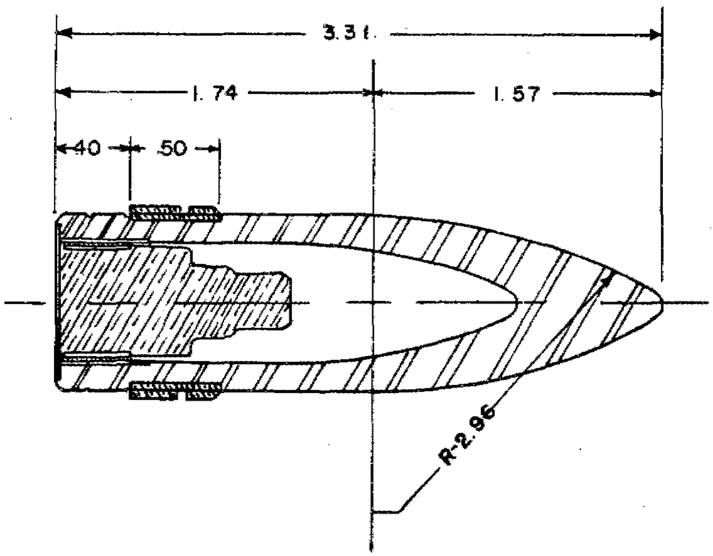


SHELL, H.E., 37MM, M63 WITH FUZE, B.D., M58

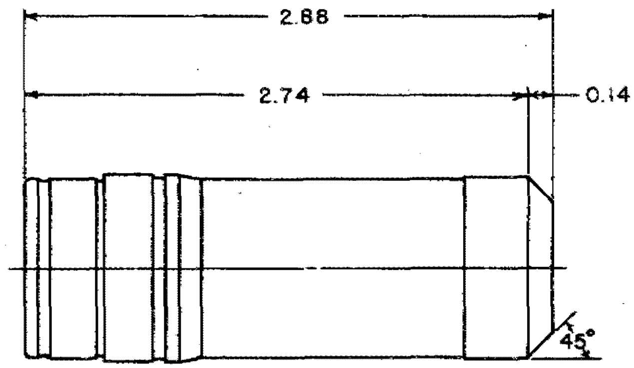
ALL DIMENSIONS IN CALIBERS



37MM H.E. SHELL T33; FUZE B.D. T136



SHELL, H.E., 37MM, T27 WITH FUZE, B.D., M58



37MM PROOF PROJECTILE M52

ALL DIMENSIONS IN CALIBERS

9. 37mm Projectiles

a. Drawings.

Shot, Armor-piercing Capped, M51	75-2-276
Shot, Armor-piercing Capped, M59	75-2-289
Shot, Armor-piercing, M74	75-2-306
Shot, Armor-piercing, M80	75-3-210
Shot, Armor-piercing Supervelocity, Mark 1 (Deformable 37/30mm)	
Shell, High Explosive, Mark 2	75-2-179
Shell, High Explosive, M54 (T12)	75-2-279
Shell, High Explosive, T2	75E-2-254
Shell, High Explosive, M63	75-2-290
Shell, High Explosive, T27	TAM 58
Shell, High Explosive, T33	TAM 1052 & 1053
Shell, Practice, M55A1	75-2-278
Projectile, Proof, M52	75-2-275 Rev. 1
Fuze, Base Detonating, M38A1	73-1-133
Fuze, Base Detonating, M58	73-1-174
Fuze, Base Detonating, T136	TAM 1054 & 1055
Fuze, Point Detonating, M56	73-2-158 to 161
Fuze, Dummy, T30 (simulates P.D. Fuze M56)	PX-91-98
Fuze, Dummy, M50 (simulates P.D. Fuze M56)	72-5-4
Plug, Closing	75-14-309A
Tracer, Red, M2	75-17-4

b. Physical Characteristics

Projectile	Fuze	Weight lb. Std.	Weight lb. Meas.	No. of Rounds	g cal.	A lb.in.^{2}	B lb.in.^{2}
A.P.C. M51	Tracer	1.92	1.917	5	1.453	.4813	3.068
A.P.C. M59	Tracer	1.91	1.905	5	1.450	.4885	3.015
A.P. M74	Tracer	1.92					
A.P. M80	Tracer	1.66	1.621	10	1.268	.4150	1.963
A.P., S.V. Mk 1	Tracer		1.18	1	1.44	.1448	1.146
H.E. Mk 2	M38A1	1.25					
H.E. T2	T30 (AL)		1.216	4	2.253	.3524	2.226

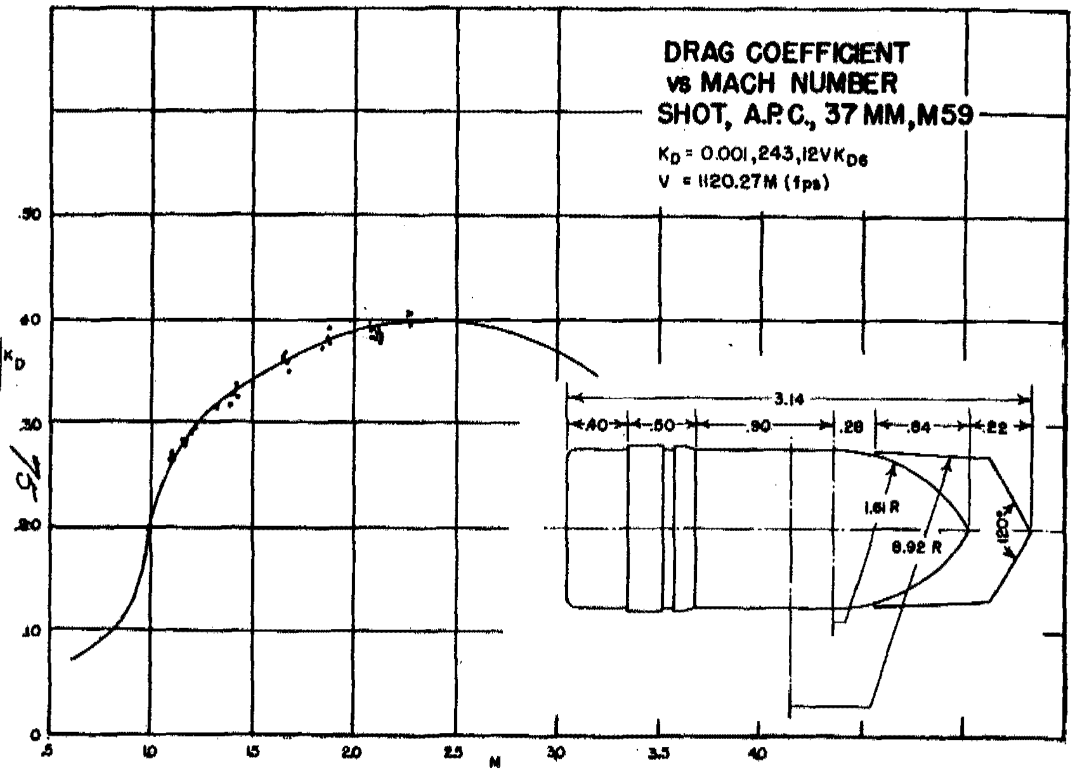
9. 37mm Projectiles (Con.)

Projectile	Fuze	Weight lb. Std.	Weight lb. Meas.	No. of Rounds	g cal.	A lb.in.^{2}	B lb.in.^{2}
H.E. M54	T30 (AL)		1.312	15	1.537	.3724	2.470
H.E. M54	T30 (brass)		1.372	6	1.636	.3770	2.905
H.E. M54	M50		1.319	1	1.520		
H.E. M54	M56	1.34	1.328	2	1.536		
H.E. M63	M58	1.61	1.592	2	1.519	.4255	3.687
H.E. T27	M58		1.590	5	1.386	.4288	2.664
H.E. T33	((BD T136) Tracer	1.71	1.713	3	1.893	.476	3.85
Proof M52		1.91			1.458	.4892	2.967

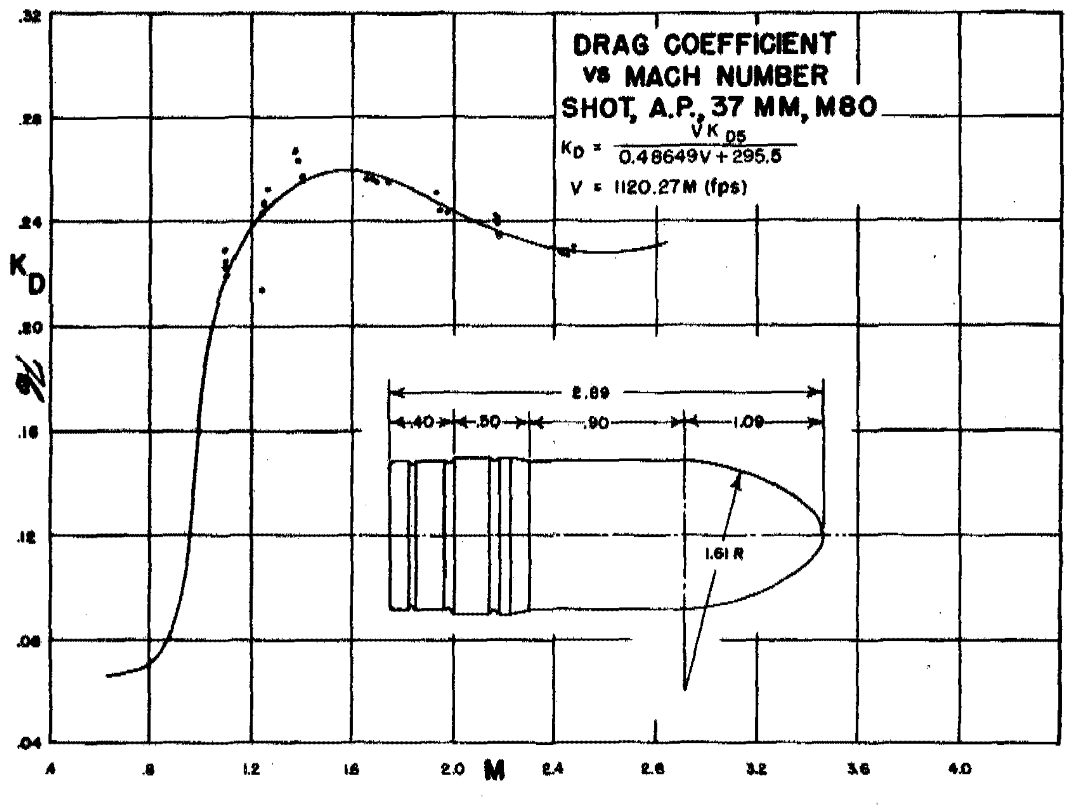
c. Drag.

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
A.P.C. M51	Tracer		Time	6	.92	2900	.101
A.P.C. M59	Plug, Wooden	BRL 284	Resist.	1	1.82	2545	.401
A.P.C. M59	Tracer		Resist.		See graph		
A.P. M74	Tracer	BRL 284	Sup.Resist.	1	1.05	2554	.231
A.P. M80	Tracer	BRL 438	Time	1	.78	1650	.202
A.P. M80	Tracer	BRL 438	Time	1	.71	3050	.146
A.P. M80	Tracer	BRL 438	Resist.		See graph		
A.P. SV,.Mk 1	Tracer	Memo 13 Sep 45	Time	8	1.24*	3660	.110
H.E. Mk 2	M38	BRL 284	Resist.	1	.89	1259	.211
H.E. Mk 2	M38	BRL 284	Resist.	1	.92	1530	.239
H.E. Mk 2	M38	BRL 284	Resist.	1	.91	1926	.226
H.E. M54	T30	BRL 138	Resist.	5	1.08	2800	.146
H.E. M54	M56	BRL 354	Time		See graph		
H.E. M54	M56		Time	5	1.04	2600	.144
H.E. T33	B.D.T136 (Tracer)	APG 471.111/ 1589	Time	6	0.95	2900	.104
Practice M55A1	Plug, Closing	BRL 284	Resist.		See graph		

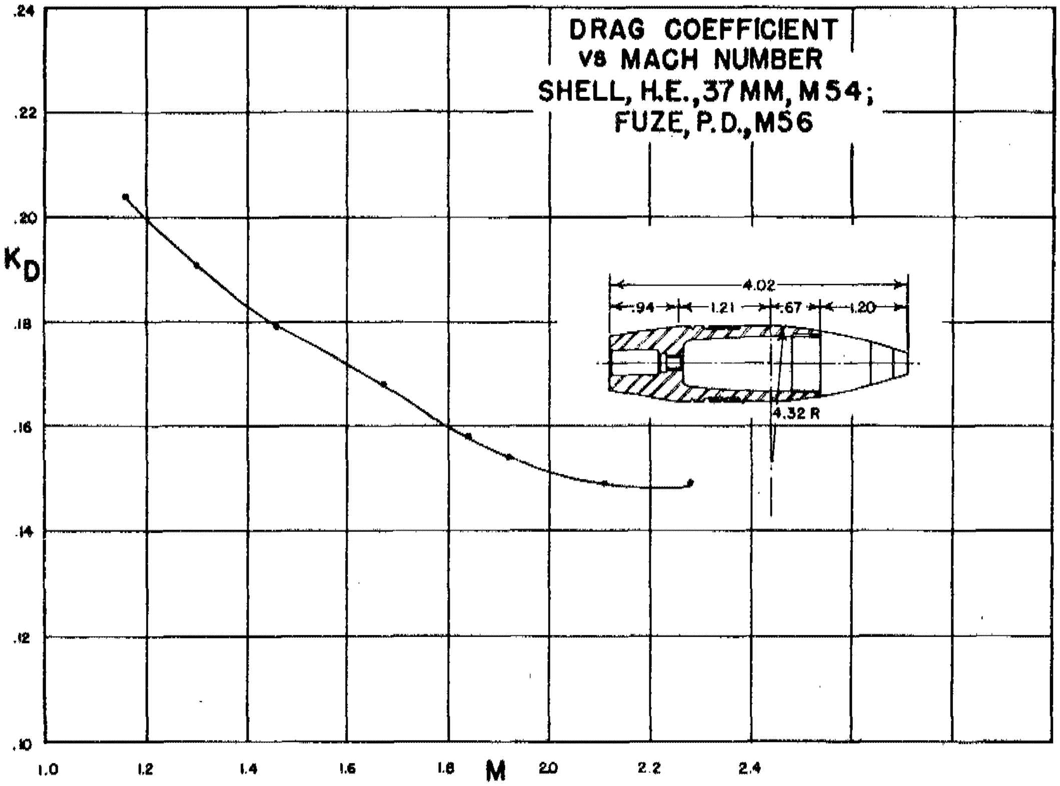
*The caliber is taken as 1.181 in. (30mm)

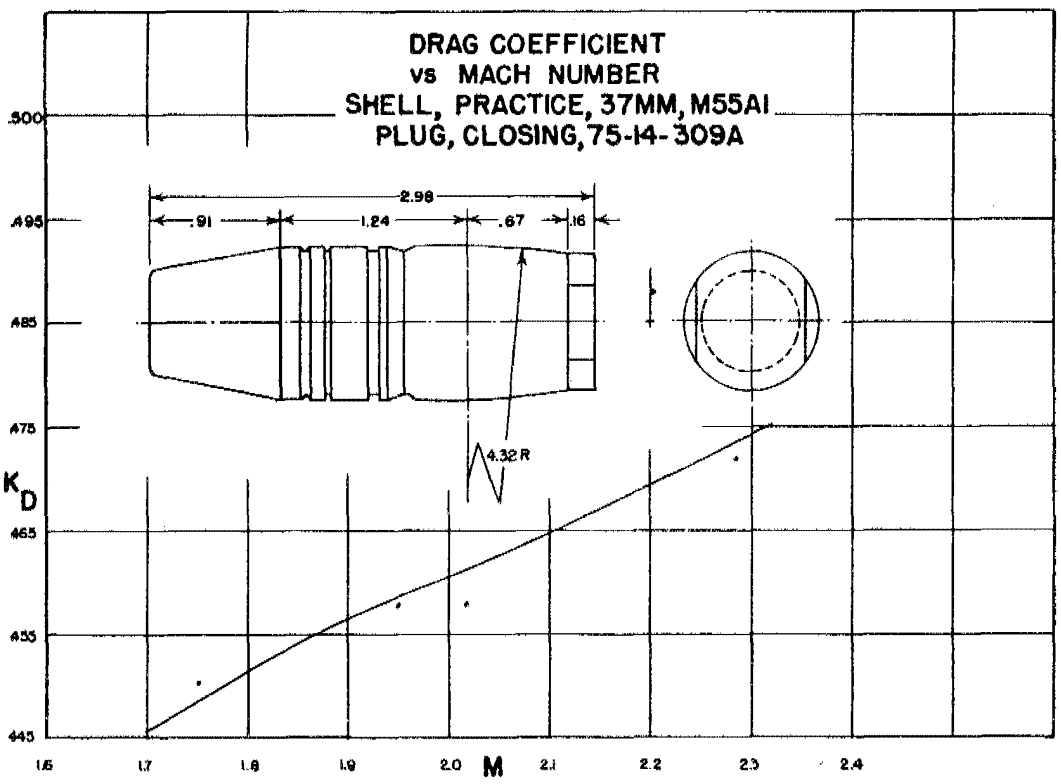


DRAG COEFFICIENT
vs MACH NUMBER
SHOT, A.P.C., 37 MM, M59
KD = 0.001,243,12VKD6
V = 1120.27M (fps)
3.14
.40
.50
.90
.28
.84
.22
1.61 R
8.92 R
120°
KD
M



DRAG COEFFICIENT
vs MACH NUMBER
SHOT, A.P., 37 MM, M80
KD = VKD5 / 0.48649V + 295.5
V = 1120.27M (fps)
2.89
.40
.50
.90
1.09
1.61 R
KD
M


DRAG COEFFICIENT
vs MACH NUMBER
SHELL, H.E., 37 MM, M 54;
FUZE, P.D., M56
4.02
.94
1.21
.67
1.20
4.32 R
K_D
.24
.22
.20
.18
.16
.14
.12
.10
1.0
1.2
1.4
1.6
1.8
M
2.0
2.2
2.4


DRAG COEFFICIENT
vs MACH NUMBER
SHELL, PRACTICE, 37MM, M55A1
PLUG, CLOSING, 75-14-309A
2.98
.91
1.24
.67
.16
4.32 R
K_D
.500
.495
.485
.475
.465
.455
.445
1.6
1.7
1.8
1.9
2.0
M
2.1
2.2
2.3
2.4

9. 37mm Projectiles (Con.)

d. Stability

Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	n cal.	s	K_M
A.P.C. M51	Tracer	BRL 225	6	1350	40	1.23	
A.P.C. M51	Tracer	BRL 225	4	2740	40	1.18	
A.P.C. M51	Tracer	BRL 225	Ave.		25	3.1	1.35
A.P.C. M59	Tracer	BRL 438	7	2800	30	12.15	0.25
A.P. M80	Tracer	BRL 438	4	1650	40	3.70	0.513
A.P. M80	Tracer	BRL 438		1650	25	9.5	0.513
A.P. M80	Tracer	BRL 438	7	3050	30	6.78	0.497
A.P., SV Mk 1	Tracer	Memo 13 Sep 45	1	3675	25	1.49	1.18
H.E. T2	T30(AL)	BRL 138	2	2800	35	1.39	1.14
H.E. M54	T30(AL)	BRL 138	1	2200	30	1.53	1.41
H.E. M54	T30(AL)	BRL 138	3	2800	35	1.19	1.33
H.E. M54	T30(brass)	BRL 138	1	2800	35	1.11	1.26
H.E. M54	T30(brass)	BRL 138	2	2800	30	1.49	1.27
H.E. M54	M56	BRL 354	10	2000	30	1.66	1.89
H.E. M63	M58	BRL 225	7	1200	35	1.22	
			5	2450	35	1.23	
			Ave.		25	2.4	1.13
H.E. T27	M58	BRLM 261	10	3100	30	10.9	0.24
H.E. T33	T136 Tracer	APG 471.111/ 1589	7	2750	25	3.81	0.85
Proof M52		BRL 225	11	2650	40	4.57	0.152

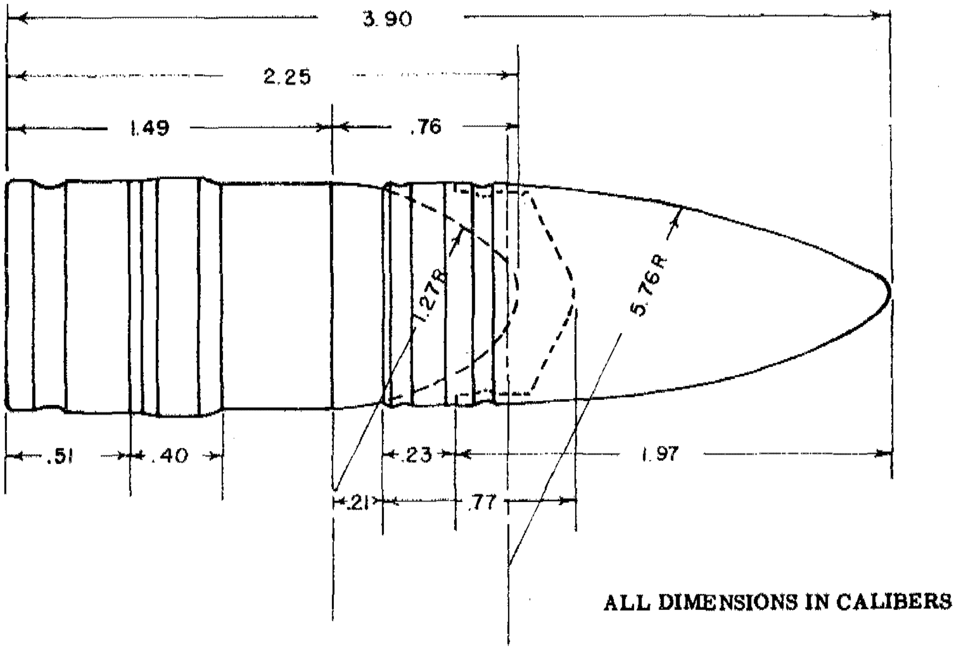
e. Drift and Damping

Projectile	Fuze	Report	Velocity ft/sec.	K_L	K_H	K_J
A.P.C. M59	Tracer	BRL 438	3000	.093	1.62	-.125
A.P. M80	Tracer	BRL 438	3100	.188	2.53	-.26
H.E. M54	M56	BRL 354 & 357	2000	.98	3.2	-.19

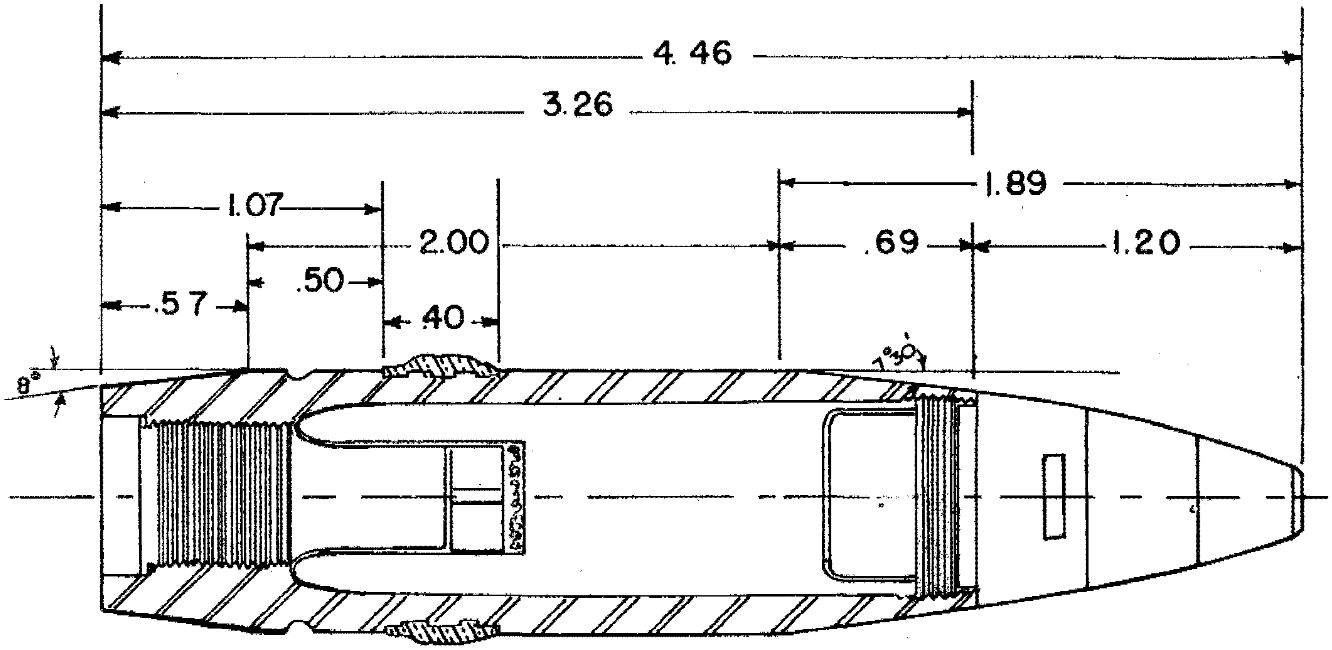
9. 37mm Projectiles (Con.)

f. Rifling of 37mm Guns and Sub-caliber Tubes (1.457")

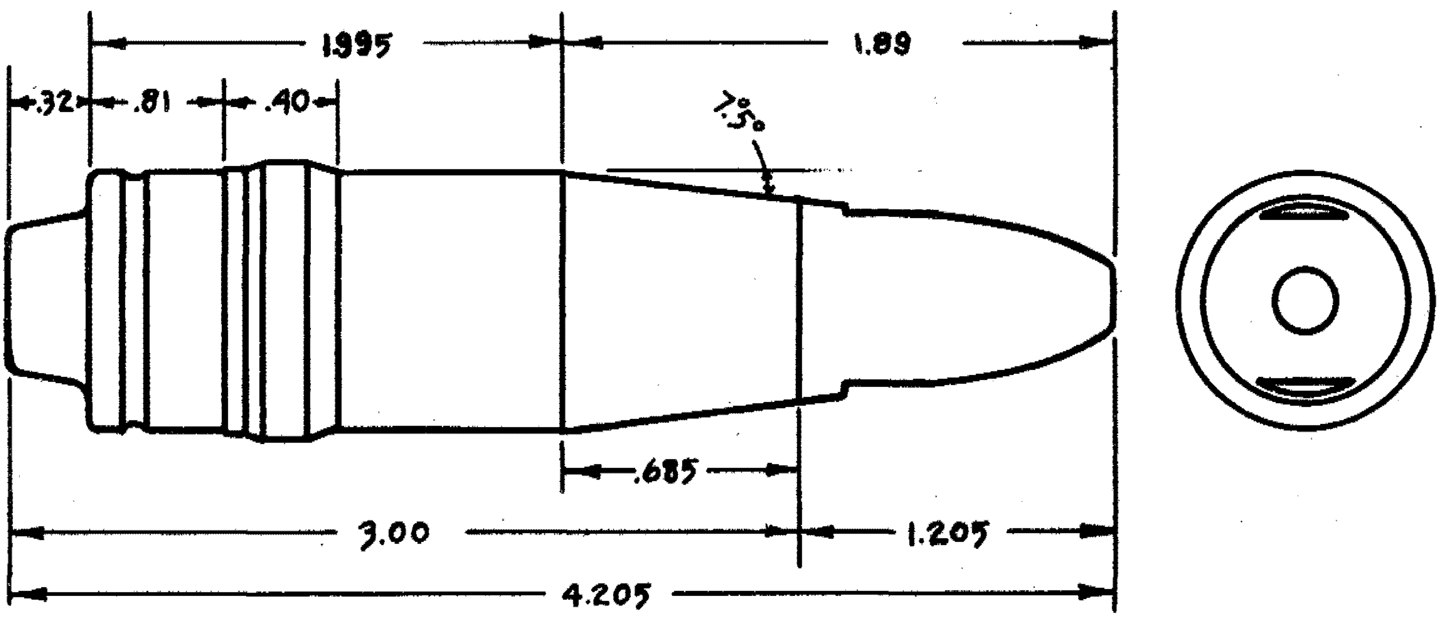
Gun or Tube	n-cal.
Antiaircraft Gun M1A2	30
Antitank Guns M3 and M3A1	25
Tank Guns M5 and M6	25
Aircraft Guns M4 and M10	25
Aircraft Guns M9 and M9A1	30
Sub-caliber Guns M1916, M1916A1, and M1916A2	29.89
Sub-caliber Guns T17, T22 and T23 (Left hand twist)	29.89
Sub-caliber Guns M12, M13, M14, M15 and M16	25
Sub-caliber Guns T12 and T14	25
Sub-caliber Gun T13	30
Sub-caliber Tube M1925 No. C-4360	40
Sub-caliber Tube G2 No. 88	30
Sub-caliber Tube M1A1 No. 7	35
Sub-caliber Tube M1A1 No. 109	30
Sub-caliber Tube M1A2	30
Sub-caliber Tube T24 (Left hand twist)	30



SHOT, A.P.C., 40MM T4E10



SHELL, Q.F.H.E., 40MM, MARK 2 T/L/ WITH FUZE, P.D., M64



SHELL, H.E., 40MM, T7; FUZE, DETONATING, MARK 27

ALL DIMENSIONS IN CALIBERS

10. 40mm Projectiles

a. Drawings

Shot, Armor-piercing Capped, T4E10	TAM 737 and 738
Shell, Quick Firing High Explosive, Mark 2 T/L/	75-2-298
Shell, High Explosive, T7	TAM 278
Shell, Practice, M91 (T1) (same contour as Q.F.H.E. Mark 2)	75-2-304
Fuze, Point Detonating, M64 and M64A1	73-2-172 and 175
Fuze, Detonating, Mark 27(Navy Bureau of Ordnance)	300423 and 300426
Fuze, Dummy, T34 (simulates M64 and Mark 27 Fuzes)	

b. Physical Characteristics

Projectile	Fuze	Weight lb. Std.	Weight lb. Meas.	No. of Rds.	g cal	A lb.in.^{2}	B lb. in.^{2}
A.P.C. T4E10	Tracer		1.975	10			
H.E. Mark 2 (with tracer)	M64A1	1.954	1.951	7			
	Mk 27	1.954	1.986				
H.E. Mark 2 (w/o bourrelet, with wood plug)	T34		1.8285	5	1.566	.6298	4.955
H.E. T7	Mk 27	1.96	1.889	5	1.595	.6130	4.253
Prac. M91	T34	1.96					

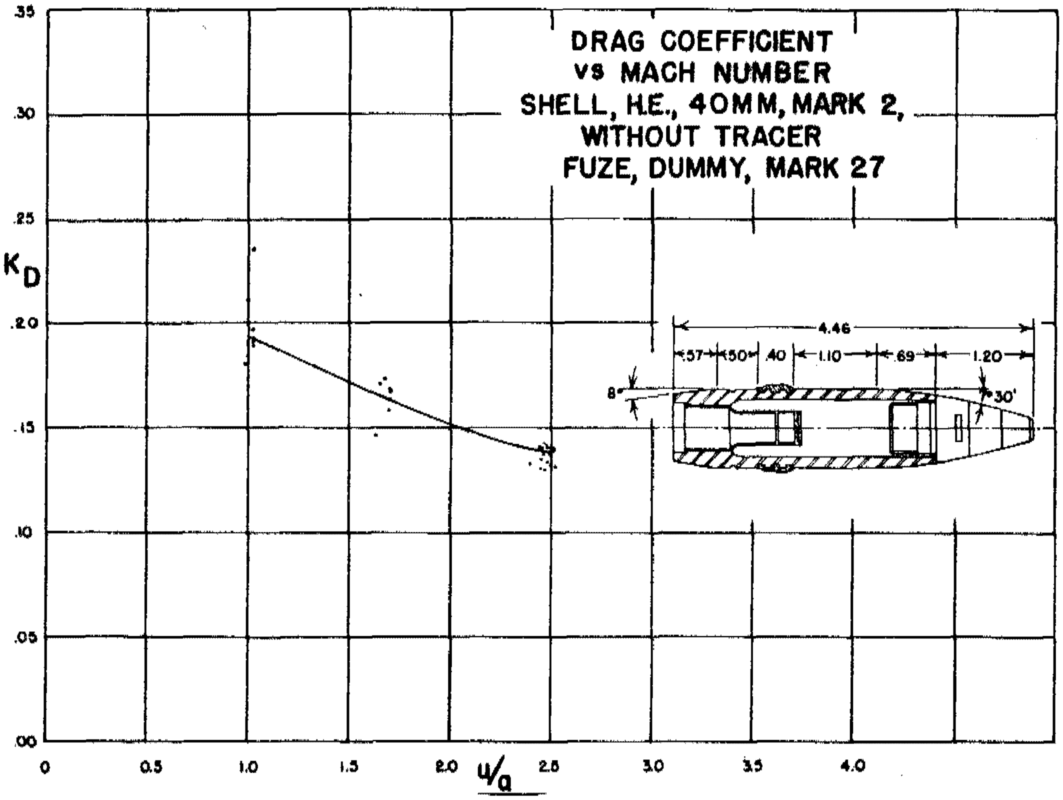
c. Drag

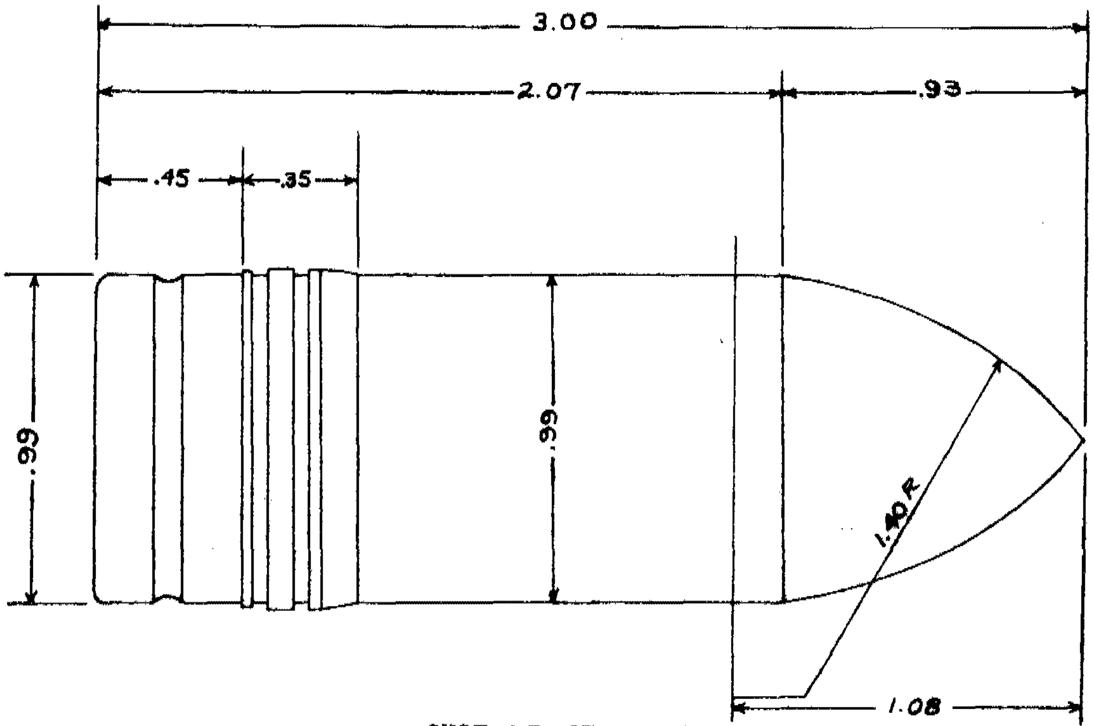
Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
A.P. T4E10	Tracer	K-I-9 Mar 44	Resist.	6	1.20	2709	.142
H.E. Mk 2 (with tracer)	M64A1	APG471.12/368	Time	5	.952	2867	.128
	Mk 27	APG471.12/368	Time	5	.927	2896	.124
H.E. Mk 2 (w/o tracer)	Dummy / Mk 27	NPG 3-45	Resist.			See graph	
H.E. T7	Mk 27	BRLM 217	Time	5	1.18	2870	.158
Prac. M91	T34	BRL 284	Resist.	5	1.07	2887	.143

d. Stability — Pitch of Rifling: 30 calibers

Projectile	Fuze	Report	No. of Rds.	Velocity ft/sec.	Mach No.	s	K_M
H.E. Mk 2	T34	BRL 252	8	1200	1.042	1.229	1.85
H.E. Mk 2	T34	BRL 252	5	2890	2.514	1.479	1.54
H.E. T7	Mk 27	BRLM 217	4	2870		2.53	0.91

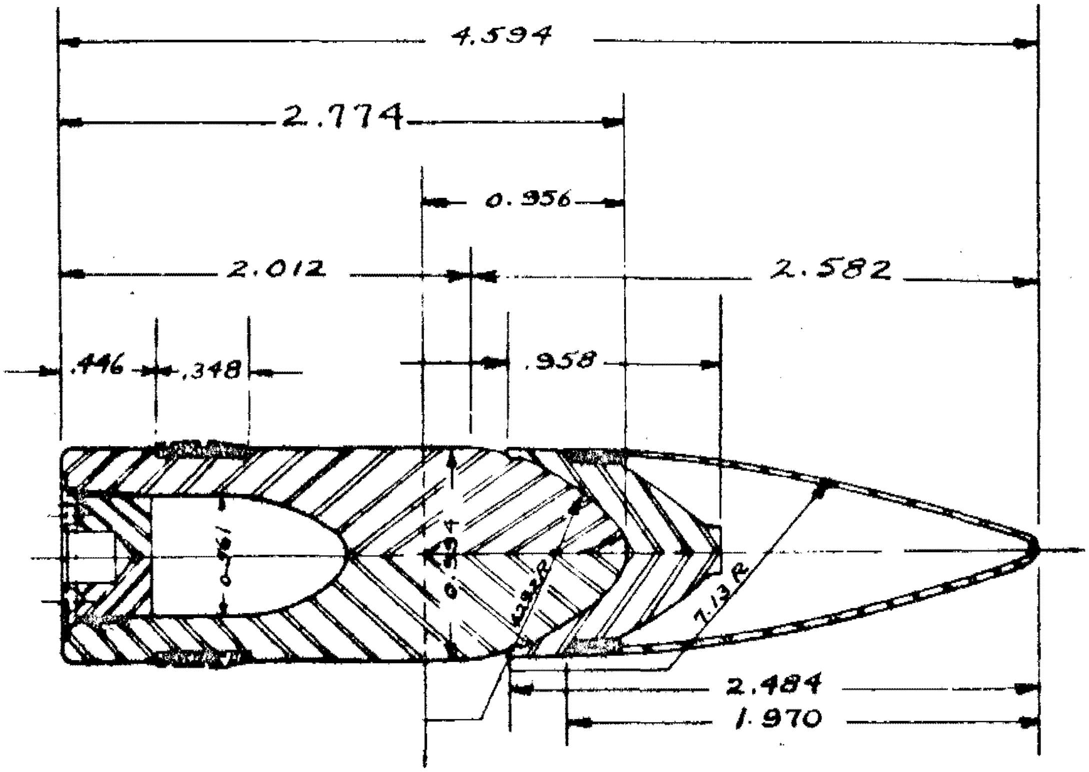
The caliber of the 40mm Antiaircraft Automatic Gun M1 is 1.575 inches.



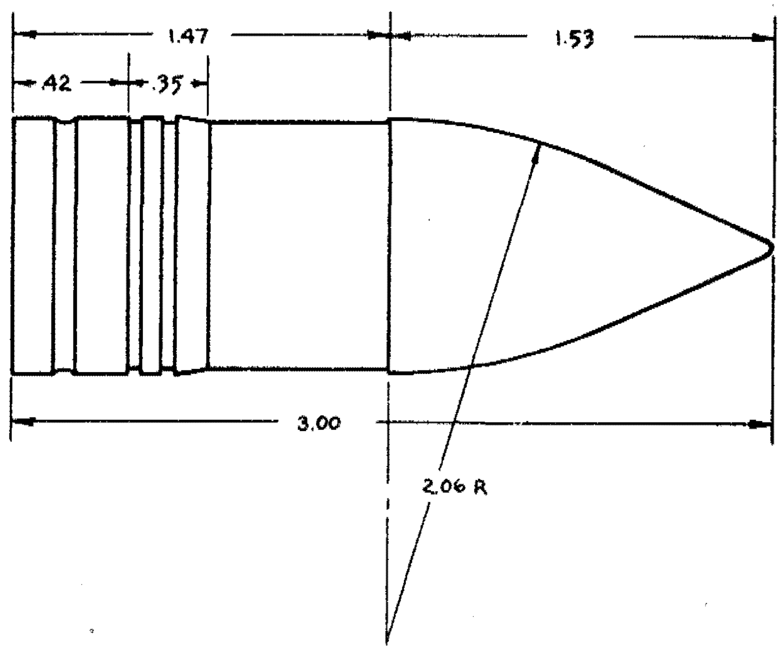


SHOT, A.P., 57MM, M70

ALL DIMENSIONS IN CALIBERS

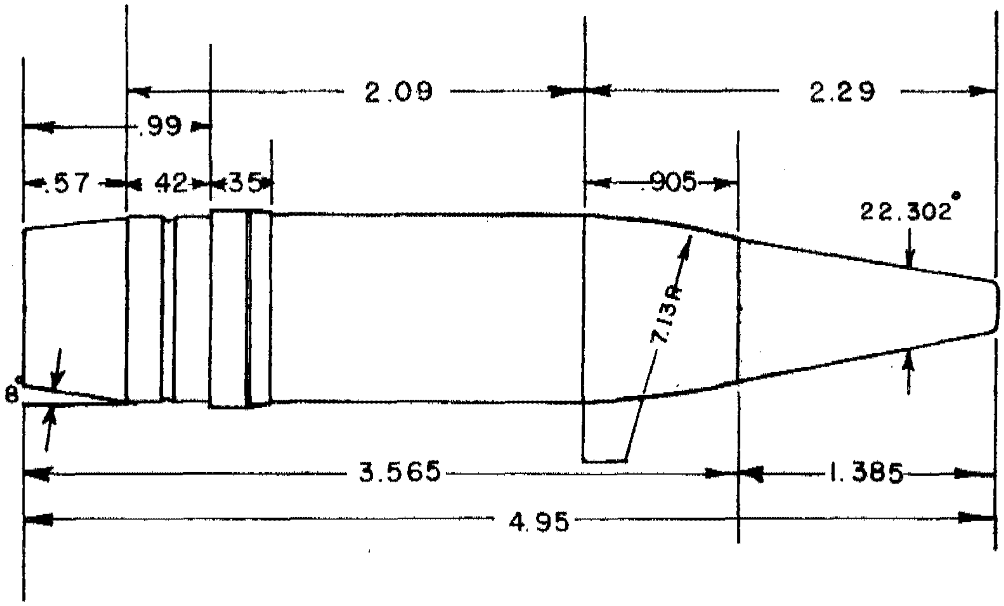


PROJECTILE, A.P.C., 57MM, M86; FUZE, B.D., M72

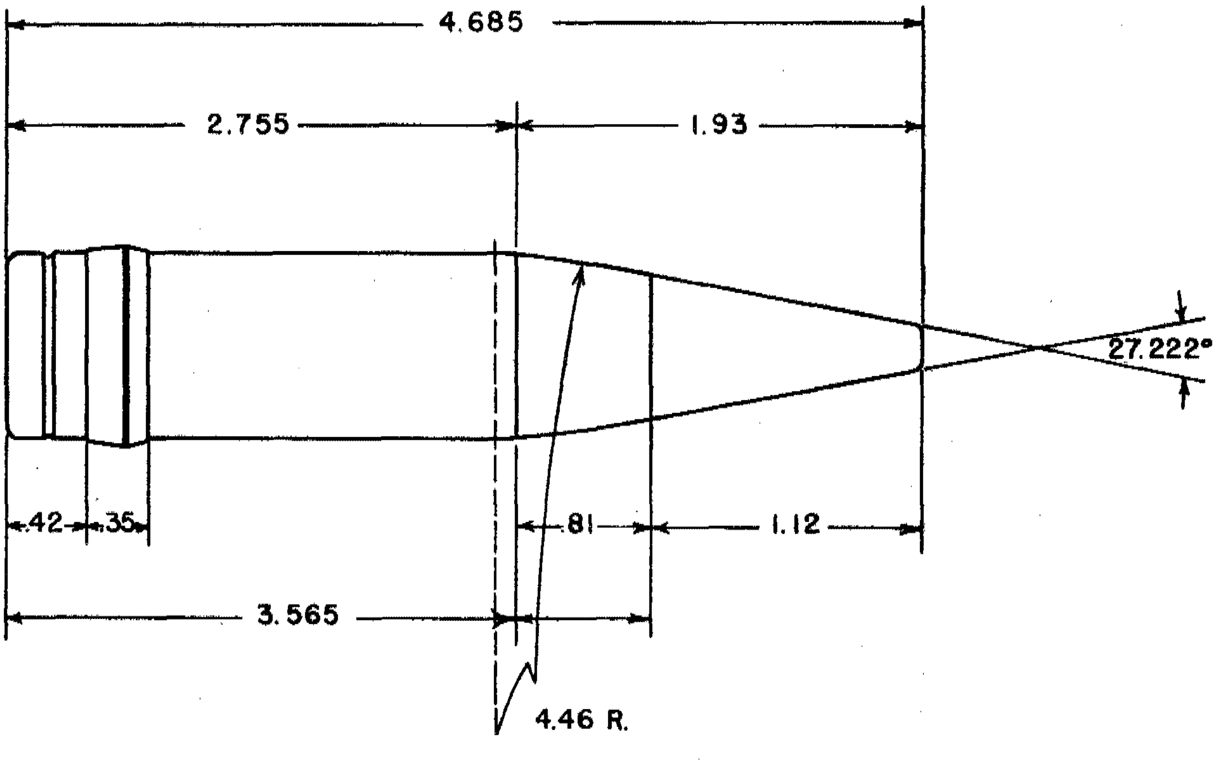


SHOT, H.V.A.P., 57MM, T14

ALL DIMENSIONS IN CALIBERS

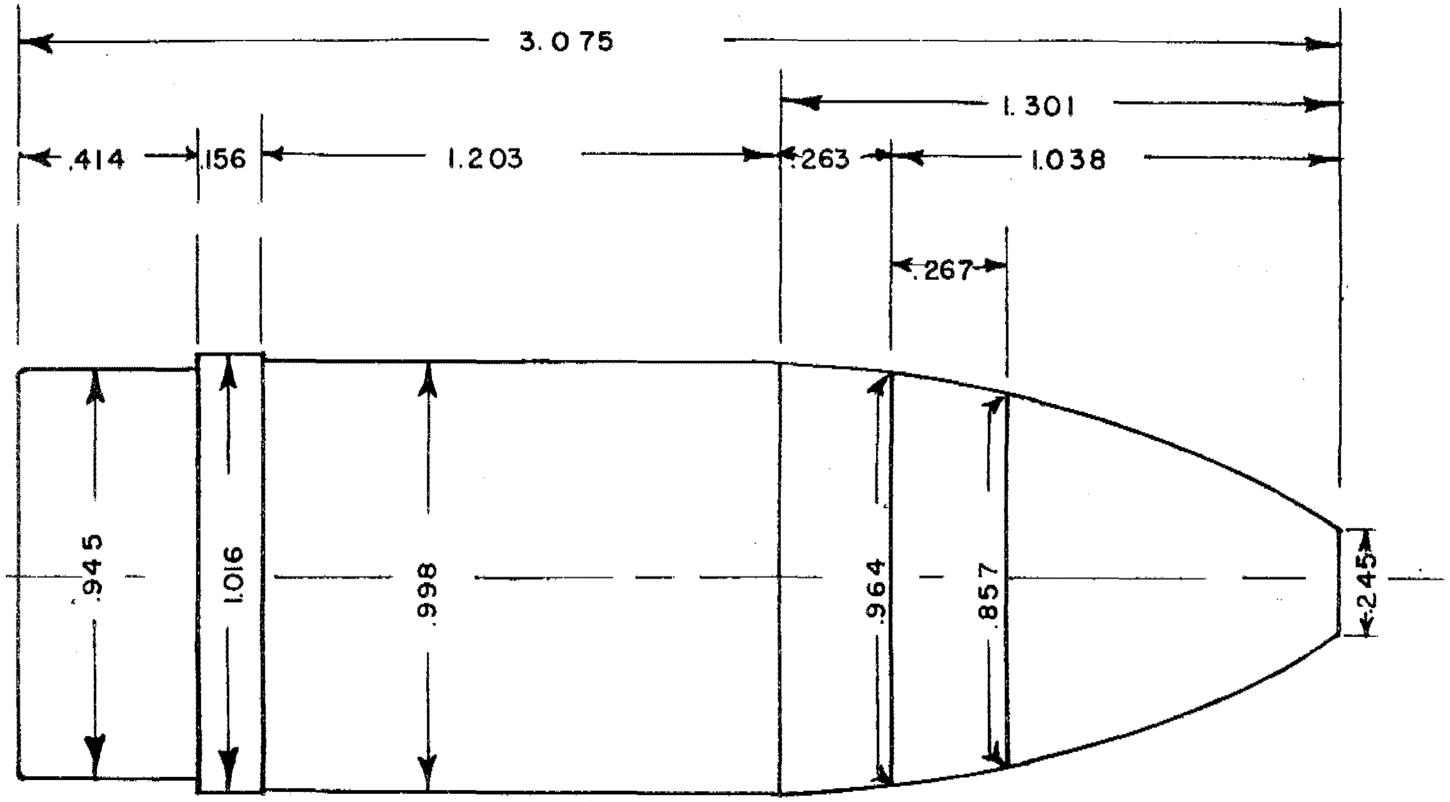


SHELL, H.E., 57MM T16 WITH FUZE, DUMMY, T66

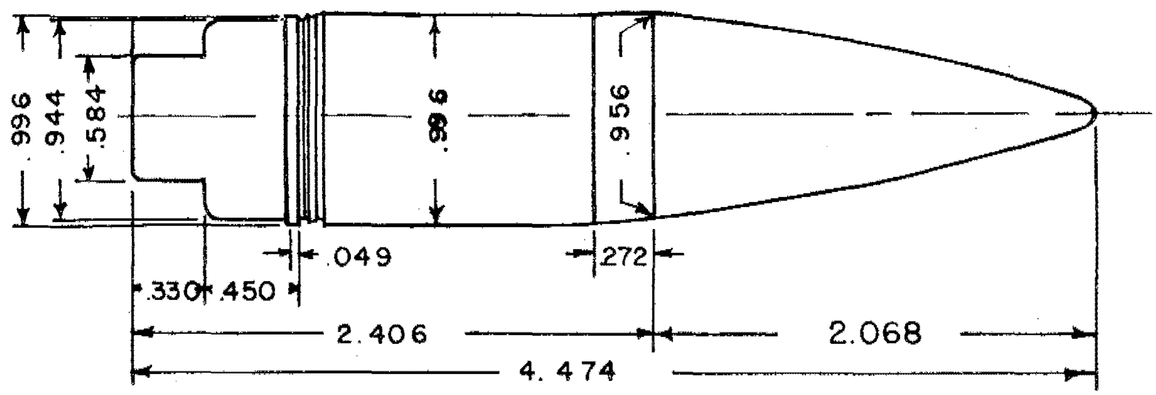


SHELL, H.E., 57MM, T18; FUZE, DUMMY, T67

ALL DIMENSIONS IN CALIBERS

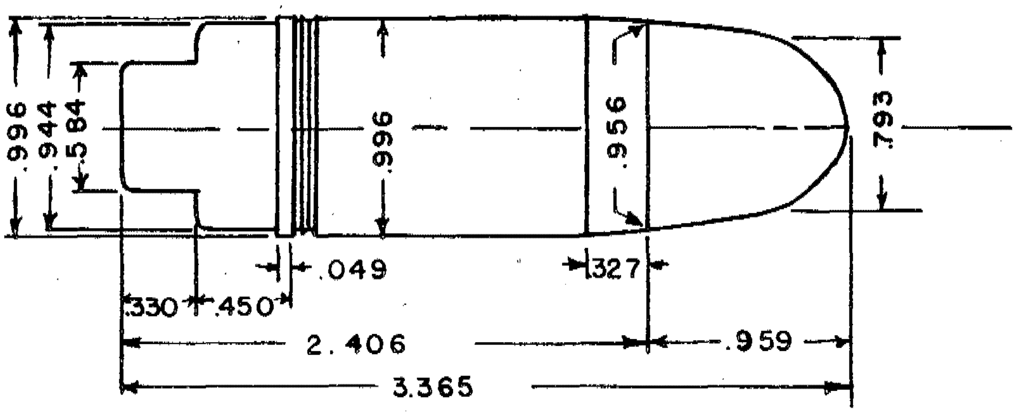


SHELL, H.E., 57MM, M306; FUZE, P.D.

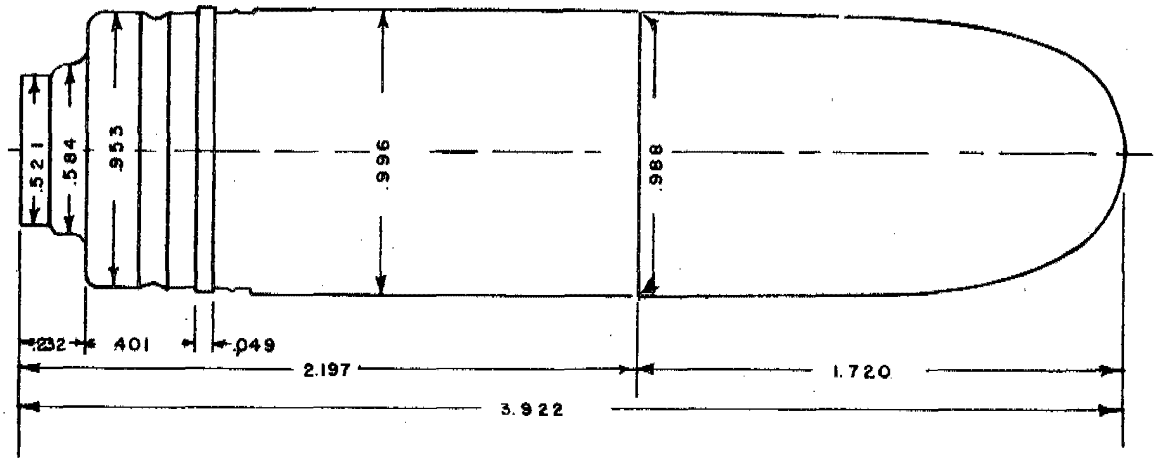


SHELL, H.E.A.T., 57MM, T20, TYPE 1A WITH FUZE, B.D., T94

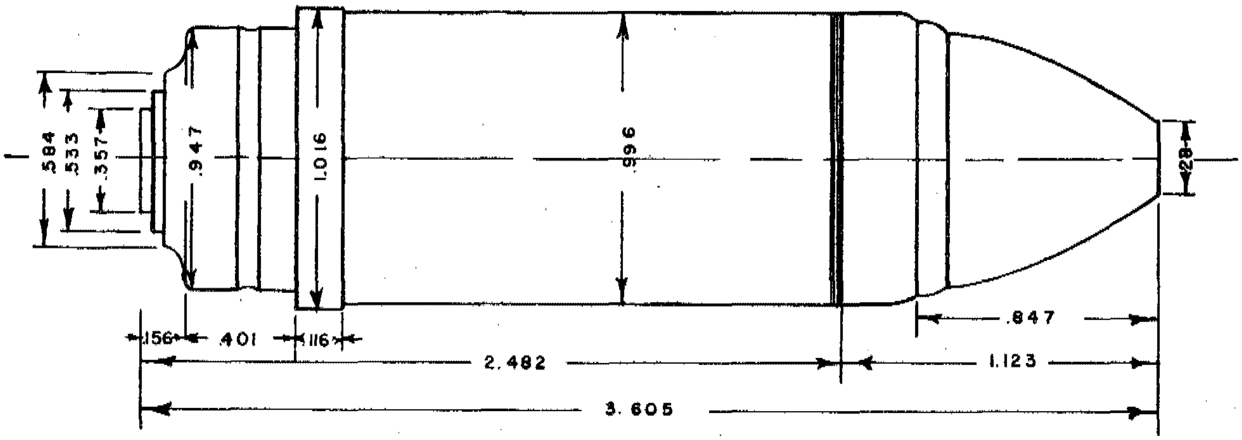
ALL DIMENSIONS IN CALIBERS



SHELL, H.E.A.T., 57MM, T20 TYPE IIA WITH FUZE, B.D., T94



SHELL, H.E.A.T., 57MM, T20E1; FUZE, B.D., T94E1



SHELL, H.E.A.T., 57MM, M307; P.I. FUZE, T123E1

ALL DIMENSIONS IN CALIBERS

11. 57mm Projectiles

a. Drawings

Shot, Armor-piercing, M70	75-2-301
Shot, Armor-piercing (57/40mm)	J&L A-1944
Shot, Target Practice, M70 (same design as A.P. Shot M70)	
Shot, Armor-piercing Capped, M86	75-2-320 and 323
Shot, Hypervelocity Armor-piercing, T14	TAM 105
Shell, High Explosive, T16	TAM 141
Shell, High Explosive, T18	TAM 158
Shell, High Explosive, M303 (T18E1) (Approximately same contour as T18)	75-2-359
Shell, High Explosive, M306 (T22)	P-73259, 73260 and 73262
Shell, High Explosive Antitank, T20, Types IA and IIA	FA CLS-V8-131
Shell, High Explosive Antitank, T20E1	P-73296 and 73310
Shell, High Explosive Antitank, M307 (T20E2)	75-2-353 and 354 and 75-14-472
Shell, Smoke (White Phosphorous) M308(T23) and T23E1 (same contour as H.E. Shell M306)	P-73258
Shell, Experimental, Types 1, 2, and 3, furnished by Office of Scientific Research and Development	Photos in BRL Report 303
Fuze, Base Detonating, M72(T56)	73-2-197
Fuze, Base Detonating, T94	TAM 624
Fuze, Base Detonating, T94E1	P-73317
Fuze, Point Initiating, M90 (T123E1)	73-2-236, 237 and 238
Fuze, Point Detonating, M85 (T83) (Approximately same contour as Dummy T67)	73-2-215
Fuze, Point Detonating (for H.E. Shell T22)	P-73255 and 73257
Fuze, Point Detonating, T119 and M89 (T119E1)	73-2-233
Fuze, Dummy, T66	TAM 142
Fuze, Dummy, T67	TAM 158
Fuze, Dummy, T126	72-5-14

11. 57mm Projectiles (Con.)

b. Physical Characteristics

Projectile	Fuze	Weight Lb. Std.	Weight Lb. Meas.	No. of Rds.	g cal.	A lb.in.^{2}	B lb.in.^{2}
A.P. Dwg J&L A-1944 57/40mm	Tracer		3.13	14	1.273	.873	6.447
A.P. M70	Tracer	6.28	6.28	17			
T.P. M70	Tracer	6.28					
A.P.C. M86	M72	7.27	7.27	5	1.912	4.359	36.23
A.P.C. M86	Plug	6.79	6.72				
Same w/o windshield	Plug	6.60	6.49	10			
H.V.A.P. T14		3.76					
H.E. T16	T66	6.53	6.66	10			
H.E. T18	T67	6.46	6.68	10			
H.E. M303	M85		6.61		1.555	4.787	41.52
H.E. M306	P.D.	2.88	2.86	3	1.237	2.18	9.89
H.E.A.T. T20	T94						
Type IA, lot 2788		2.45	2.38	3	1.299	1.737	9.04
Type IA, lot 2935		2.90	2.87	3	1.518	2.097	13.17
Type IIA, lot 2780		2.73	2.70	1	1.429	2.014	10.52
Type IIA, lot 2780		2.65	2.63	2	1.408	1.980	10.39
Type IIA, lot 2936		2.77					
H.E.A.T. T20E1	T94E1		2.90	5	1.519	2.50	15.57
H.E.A.T. M307*	M90	2.75	2.71	5	1.353	2.20	10.42
H.E.A.T. M307**	M90	2.75	2.70	6	1.269	2.066	9.756
W.P. M308	T119	2.75	2.39	5	1.137	1.82	7.69
W.P. T23E1	T126		2.68	3	1.093	1.75	6.40
W.P. M308	M89	2.75	2.64	3	1.044	1.79	6.06
Exp., O.S.R.D.	Dummy						
Type 1			4.91	2	1.872	3.80	40.05
Type 2			5.49	2	2.060	4.26	55.57
Type 3			5.15	2	1.953	3.98	45.52

*P.A. Lot E-T45-187 (fired 16 Sep 44)

**M.G. lot 1 (made according to Rev. 1 of Drg. 75-2-353, dated 3 March 45, which differs from the original in several interior dimensions).

11. 57mm Projectiles (Con.)

c. Drag

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
A.P. Dwg J&L A-1944 57/40mm	Tracer	Memo 2 Sep 45	Time	8	1.52*	3970	.127
{A.P. M70	Tracer	K-I-9 Mar 44	Resist.	1	1.285	2663	.278
{A.P. M70	Tracer	K-I-9 Mar 44	Resist.	1	1.28	2853	.270
T.P. M70	Tracer	BRL 284 Aug 42	Resist.	1	1.21	2797	.257
{A.P.C. M86**	M72	FR P32910	Resist.	6	.88	1968	.133
A.P.C. M86	M72	K-I-9 Mar 44	Resist.	6	1.11	2650	.134
A.P.C. M86	Plug	BRL 284 May 43	Resist.	6	1.08	2729	.126
Same w/o windshield)	Plug	K-I-9 Mar 44	Resist.	1	1.65	2676	.356
{H.V.A.P. T14		Memo June 43	Resist.	1	.77	3699	.153
{H.V.A.P. T14		Memo June 43	Resist.	1	.80	2918	.167
H.E. T18	T67	K-I-9 Mar 44	Resist.	6	1.13	2797	.129
H.E. M306	M89	APG 474.1/165	Time	1	.86	978	.105
H.E.A.T. M307†	M90	APG 474.1/165	Time	1	.98	956	.113

*The caliber is taken as 1.575 in. (40mm)

**Modified by machining the rotating band to the body diameter, fitted with a sabot and fired from a 75mm Howitzer M1A1.

†M.G. lot 1.

d. Stability

Projectile	Fuze	Report	No. of Rds.	Velocity ft/sec.	n cal.	s	K_M
A.P. Dwg. J&L A-1944 57/40mm	Tracer	Memo 12 Sep 45	6	3980	30	2.73	.661
A.P.C. M86	M72	BRLM 266	4	2700	30	2.17?	1.07?
H.E. T16	T66	BRLM 246	6	2800	30	1.185	
H.E. T18	T67	BRLM 246	8	2800	30	1.735	
H.E. M303	M85	APG 471.5213/222	10	2700	30	1.62	2.19
H.E. M306	P.D.	BRLM 300	4	1176	30	1.62	1.31
H.E.A.T. T20	T94	BRLM 300					
Type IA			3	1244	20	1.51	2.10
Type IIA			3	1218	30	1.00?	1.67?
H.E.A.T. T20E1	T94E1	BRLM 319	7	1200	25	1.15	2.235

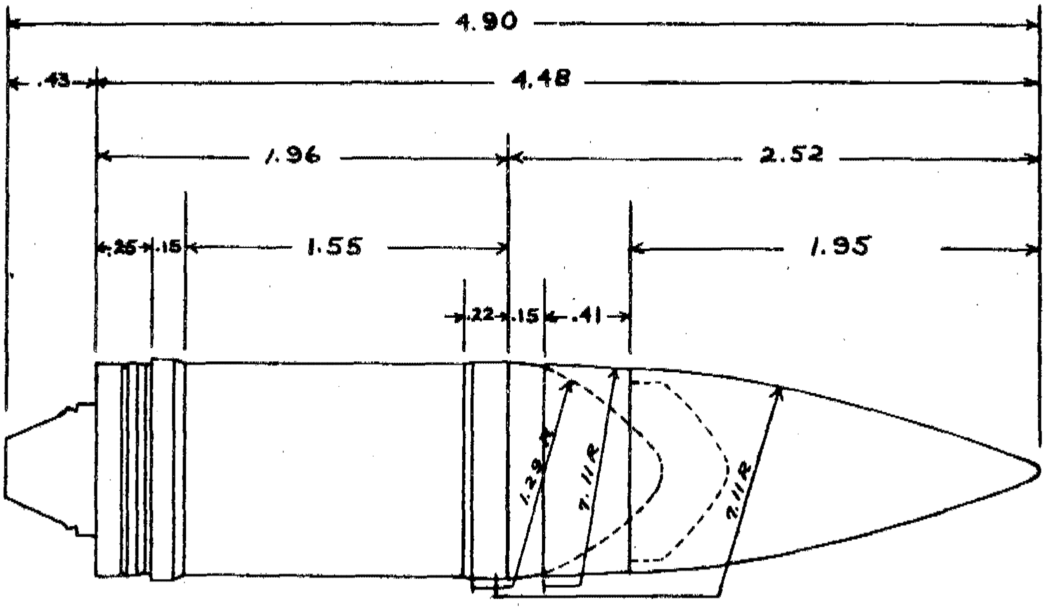
11. 57mm Projectiles (Con.)

Projectile	Fuze	Report	No. of Rds.	Velocity ft/sec.	n cal.	s	K M
H.E.A.T. M307*	M90	BRLM 348D	4	1200	30	1.34	1.53
H.E.A.T. M307**	M90	APG 474.1/165	6	1215	30	1.70	1.15
W.P. M308	T119	BRLM 348D	5	1200	30	2.56	0.70
W.P. T23E1	T126	BRLM 348D	5	1200	30	2.93	0.71
W.P. M308	M89	Memo Aug 45		1200	30	1.97	1.29
					25	3.17	1.16
Exp., O.S.R.D.	Dummy	BRL 303					
Type 1			1	1700	30	1.013?	
Type 2			2	1700	30	1.003?	
Type 3			3	1700	30	1.017?	

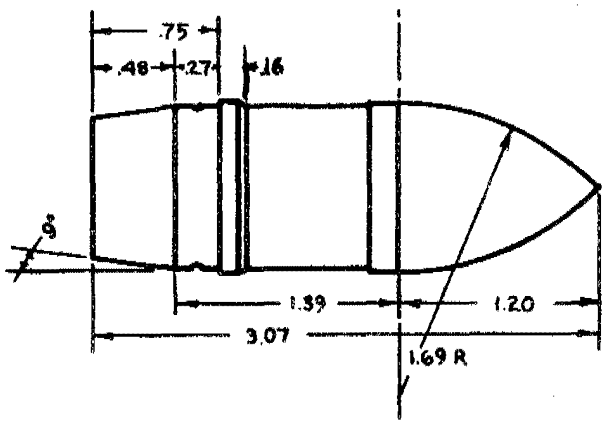
*PA. lot E-T45-187 ** M.G. lot 1

e. Rifling of 57mm Guns (2.244")

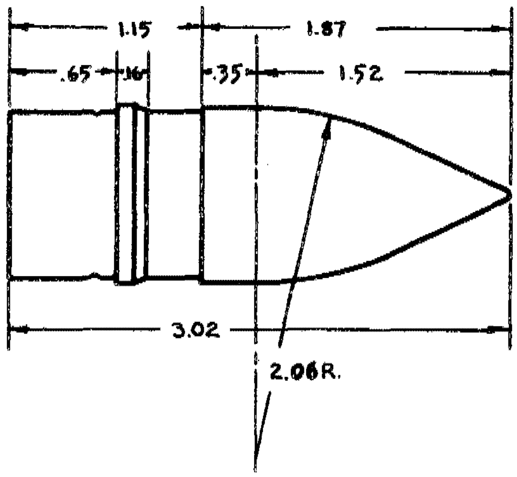
Gun	n-cal
Antitank Gun M1	30
Rifle T15E2	30
Rifle T15E3	20
Rifle T15E6-3	25
Rifle T15E9	25
Rifle M18 (T15E13)	30



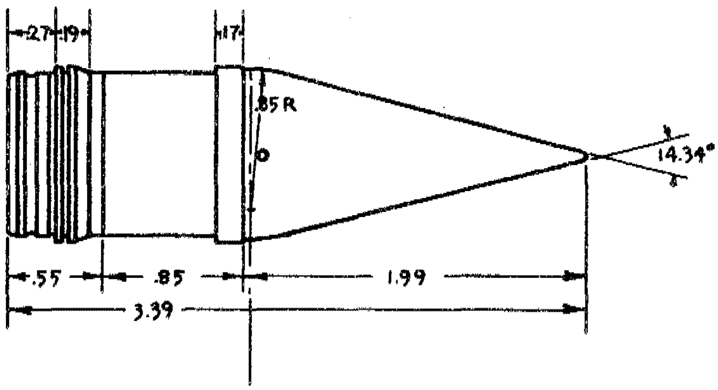
PROJECTILE, A.P.C., 75MM, M61; B.D. FUZE M66A1 ALL DIMENSIONS IN CALIBERS



SHOT, A.P., 75MM, M72

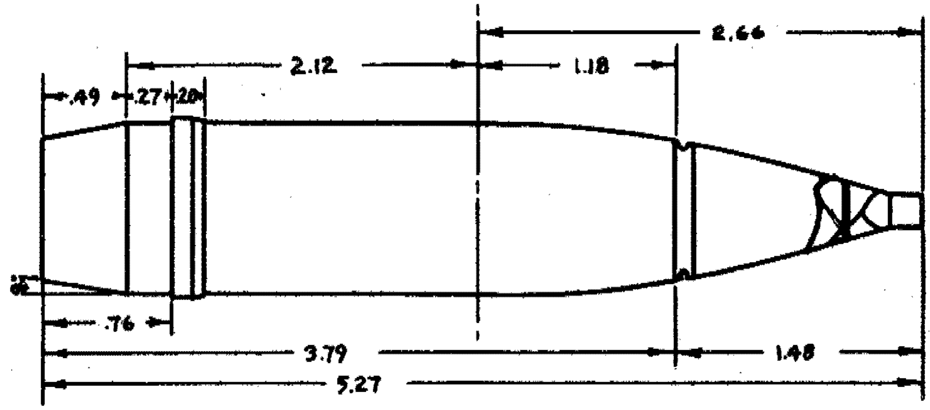


SHOT, H.V.A.P., 75MM, T27

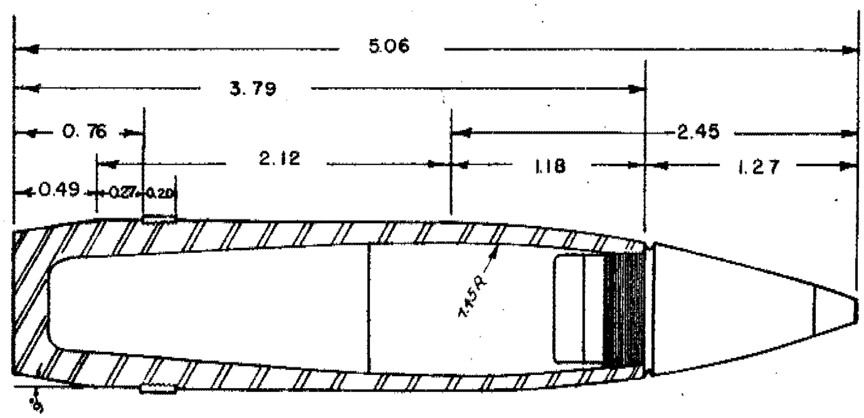


SHOT, H.V.A.P., 75MM, T45

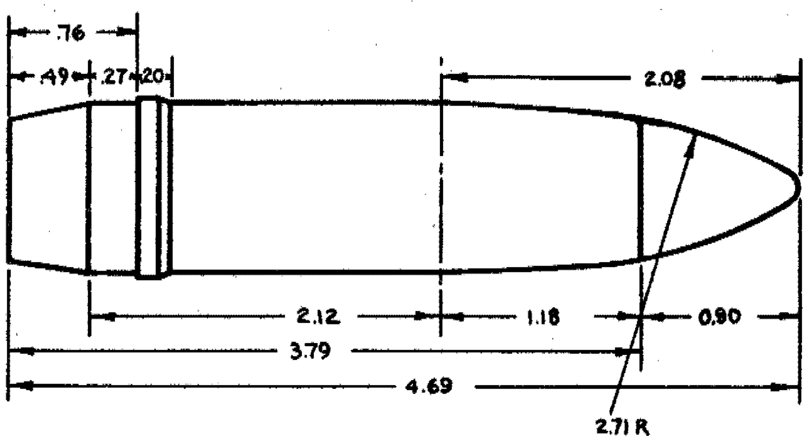
ALL DIMENSIONS IN CALIBERS



SHELL, H.E., 75MM, M48; FUZE, P.D., M39A2

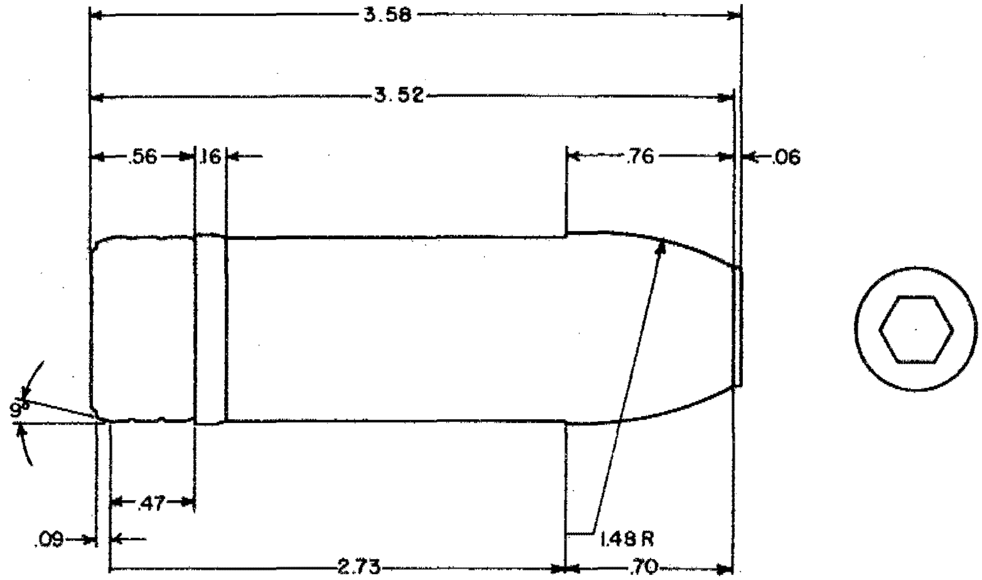


SHELL, H.E., 75MM, M48 WITH FUZE, P.D. M48

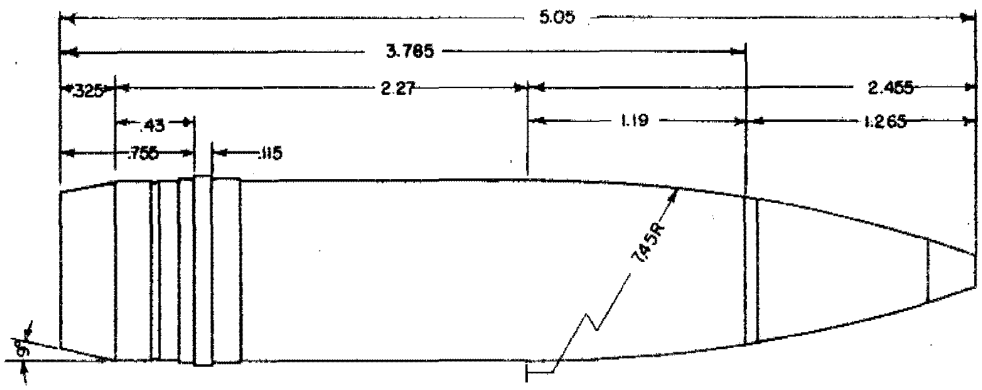


SHELL, H.E., 75MM, M48; FUZE, C.P. M78

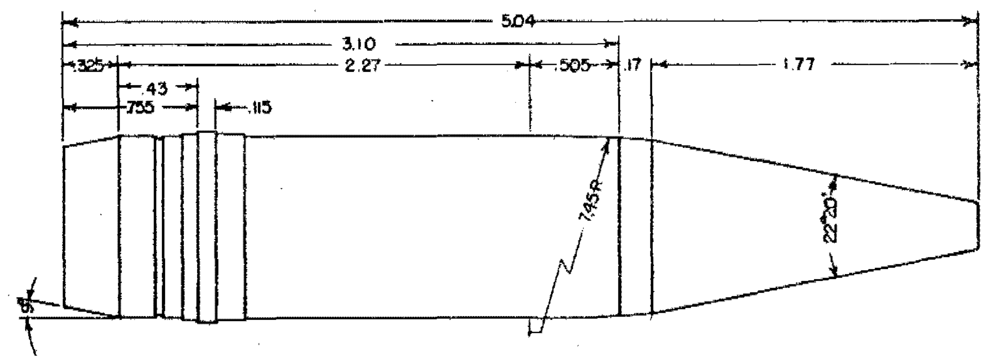
ALL DIMENSIONS IN CALIBERS



SHELL, H.E., 75MM, MARK I; HEXAGONAL PLUG

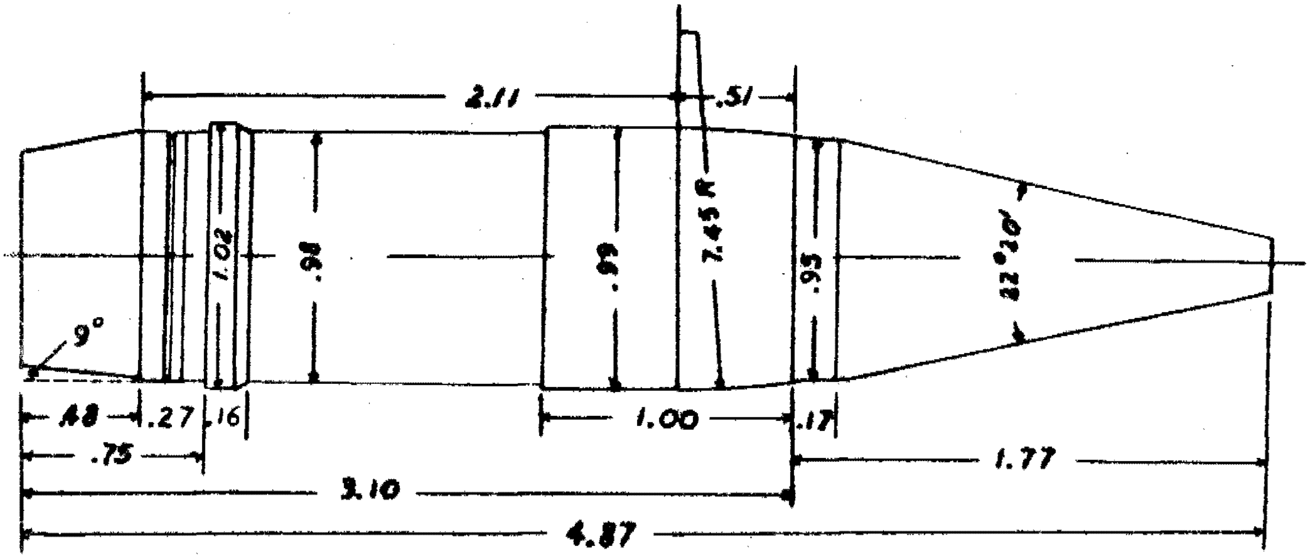


75MM H. E. SHELL, M309; FUZE P.D., M48

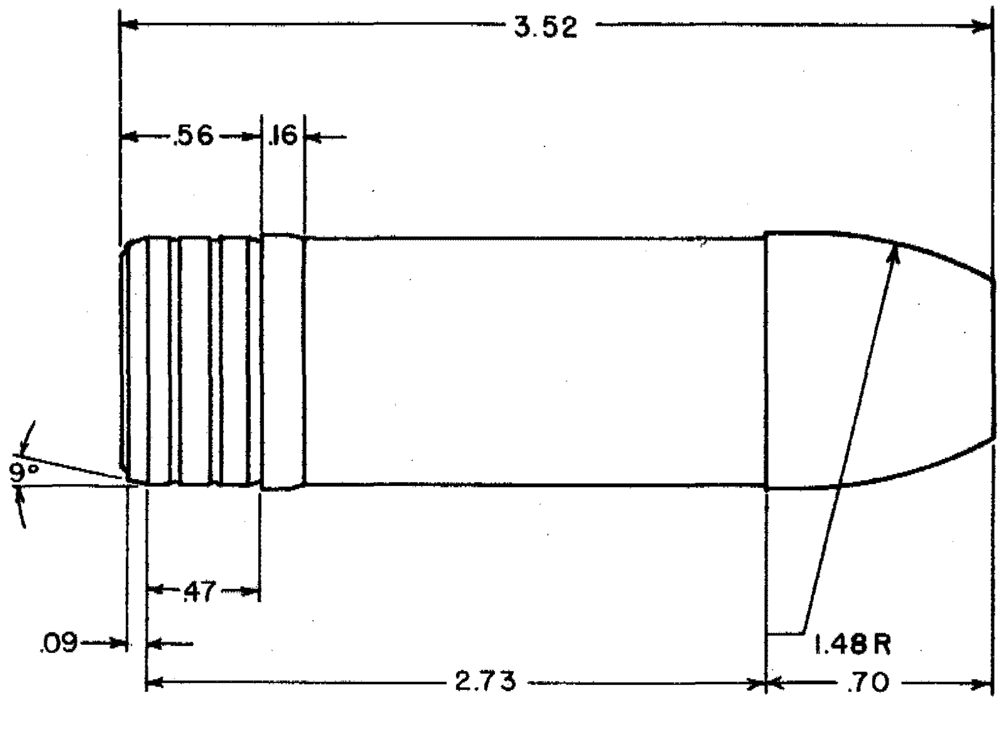


75MM H.E.A.T. SHELL M310; FUZE B.D., M62

ALL DIMENSIONS IN CALIBERS

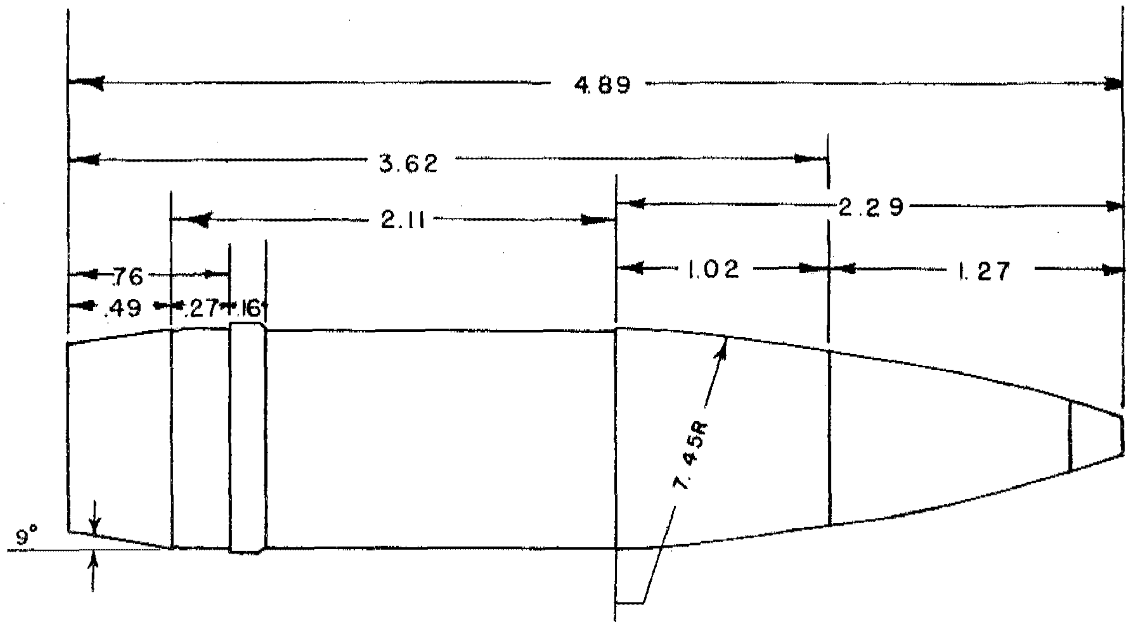


SHELL, H.E.A.T., 75MM, M66

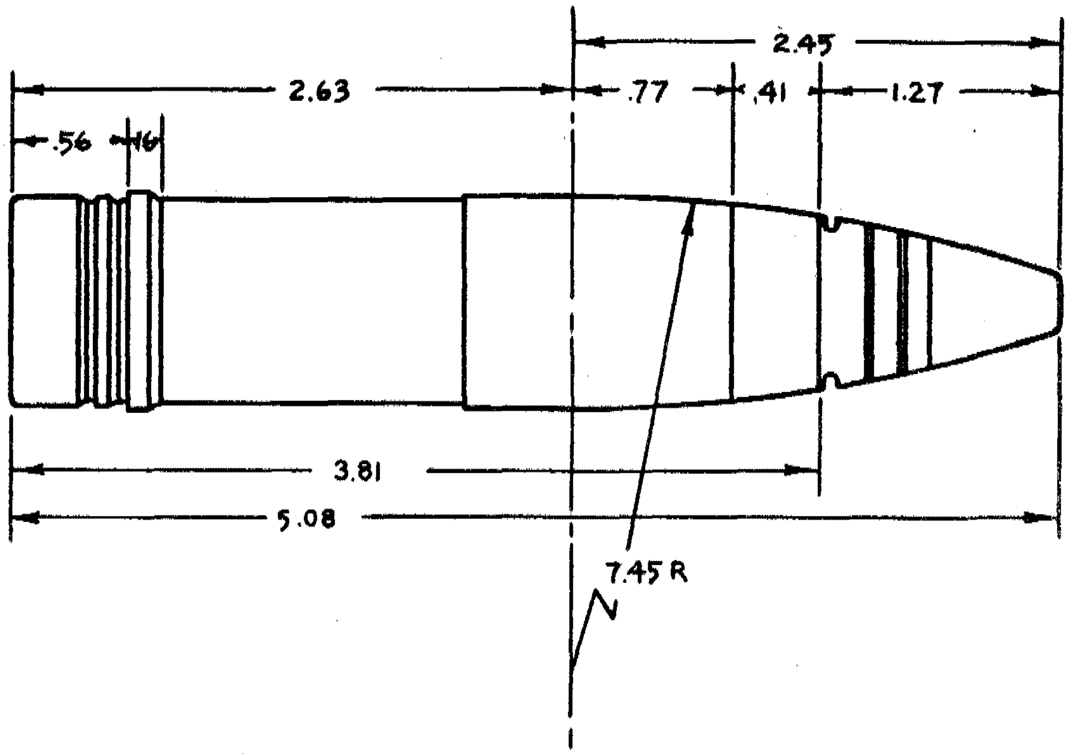


SHELL, CHEM., 75MM, MARK 2; ROUND WOOD PLUG

ALL DIMENSIONS IN CALIBERS



SHELL, CHEM., 75MM, M64 WITH FUZE, P.D., M48



SHELL, SMOKE, 75MM, T19(BE); FUZE, T.SQ., M54

ALL DIMENSIONS IN CALIBERS

12. 75mm Projectiles

a. Drawings.

Projectile, Armor-piercing Capped, M61 (T12)	75-2-291 and 326
Shot, Armor-piercing, M72	75-2-305
Shot, Hypervelocity Armor-piercing, T27	TAM 106
Shot, Hypervelocity Armor-piercing, T45	75-2-381, 382 and 363
Shell, High Explosive, M48 (T3E1)	75-2-255
Shell, High Explosive, Mark 1	75-2-164
Shell, High Explosive, M309 (T38)	75-2-365
Shell, High Explosive Antitank, M66	75-2-314 and 315 and 75-14-351
Shell, High Explosive Antitank, M310 (T39)	75-2-366
Shell, Chemical, Mark 2	75-2-171
Shell, Chemical, M64	75-2-294
Shell, Smoke, T19 (Base Ejection)	P-42291, 42292 and 42293
Shell, Smoke (WP), M311 (T40)	75-2-371
Fuze, Base Detonating, M66A1	73-2-178
Fuze, Base Detonating, M62	73-2-168
Fuze, Point Detonating, M39A2	73-2-85
Fuze, Point Detonating, M48 (T3)	73-2-140
Fuze, Point Detonating, M57	73-2-138
Fuze, Concrete Piercing, M78 (T105 Type 6)	73-2-214
Fuze, Mechanical Time, M43 (T12)	73-7-29
Fuze, Time and Superquick, M54	73-3-154
Fuze, Experimental, National Defense Research Committee (Same contour as M43, M48, and M54 fuzes)	
Fuze, Experimental, T81	

b. Physical Characteristics

Projectile	Fuze	Weight Lb. Std.	Weight Lb. Meas.	No. of Rounds	g cal.	A lb.ft.^{2}	B lb.ft.^{2}
A.P.C. M61	M66A1	14.90					
A.P.C. M61	Plug	14.4					
(same w/o windshield)	Plug		13.42				
(same w/o cap or windshield)	Plug		12				
A.P. M72	Tracer	13.94					
H.V.A.P. T27							

12. 75mm Projectiles (Con.)

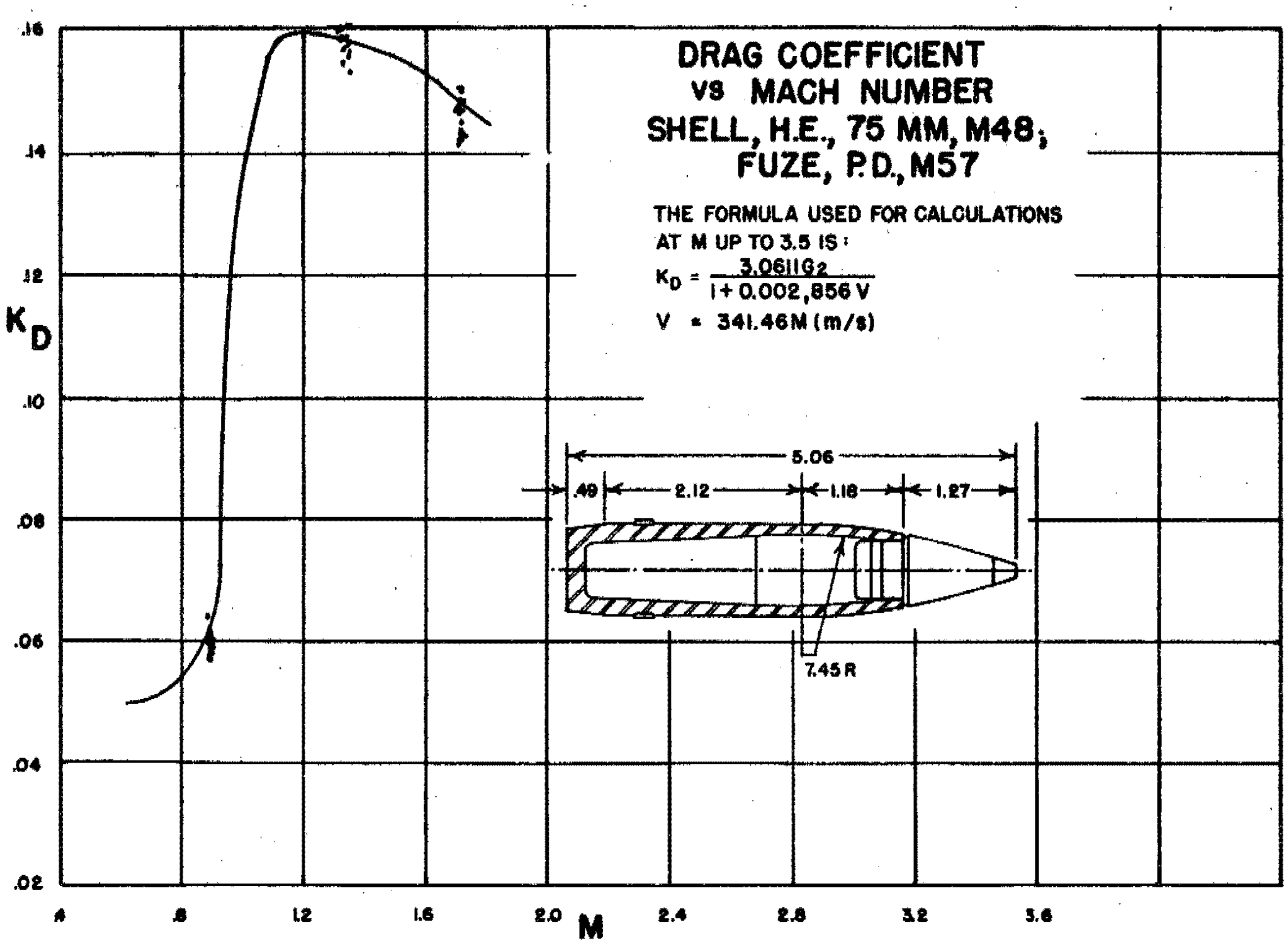
Projectile	Fuze	Weight Lb. Std.	Weight Lb. Meas.	No. of Rounds	g cal.	A lb.ft.^{2}	B lb.ft.^{2}
H.V.A.P. T45	Tracer	8.31	8.42	2	0.967	.0455	0.1977
H.E. M48	M39A2		14.96	17	2.044	.1239	1.542
H.E. M48	M43	14.70	14.99	16	2.043	.1260	1.523
H.E. M48	M48	14.70			2.037	.1259	1.495
M48 Empty	T81		14.7	6	2.04 approx.		
H.E. M48	NDRC		14.78	5	1.918	.1272	1.290
H.E. M48	M78	15.42	15.47				
H.E. Mk 1	Hex. Plug		12.37				
H.E. M309	M48	14.40	14.4	6			
H.E. M309 (Sim. W.P. M311)	M48		15.1	5			
H.E.A.T. M310	M62		13.1	7			
H.E.A.T. M66	M62	13.10	13.06	4	1.656	.1163	1.092
H.E.A.T. M66	T93		13.20				
Chem. M64	M48	15.41	14.85	5	1.940	.1244	1.413
Chem. T19	M54	14.80	14.72	3	1.96	.1255	1.386

c. Drag

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
A.P.C. M61	M66A1	K-I-9 Mar 44	Resist.	6	.985	2000	.147
A.P.C. M61	Plug	BRL 284 Aug 42	Resist.	6	.96	2000	.44
Same w/o windshield	Plug	BRL 284 June 42	Resist.	1	1.04	1000	.136
					.92	1500	.239
					1.03	2000	.252
Same w/o cap or windshield	Plug	BRL 284 June 42	Resist.	1	1.06	1000	.139
					1.17	1500	.304
					1.26	2000	.308
A.P. M72	Tracer	BRL 284 Aug 42	Resist.	5	1.41	2000	.229
H.V.A.P. T27		Memo June 43	Resist.	1	.923	1978	.227
					.852	2774	.181
H.V.A.P. T45	Tracer	Memo May 45 / APG 471.121/50	Time	6	1.11	2970	.118
			Resist.	6	1.10	2940	.118
H.E. M48	M78	K-I-9 May 44	Resist.	2	1.39	1855	.183
H.E. M48	M57			See graph			

12. 75mm Projectiles (Con.)

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
H.E. Mk 1	Hex. Plug	BRL 166 July 41	Resist.	1	1.47	2037	.357
		BRL 166 Oct 41	Resist.	1	1.11	1680	.287
H.E. Mk 1	Round Wood Plug	K-I-9 March 44	Resist.	1	0.84	1095	.148
					1.24	1935	.307
H.E. M309	M48	APG 474.1/67	Time	2	1.08	1000	.077
H.E. M309 (Sim. W.P. 311)	M48	APG 474.1/67	Time	2	1.06	1000	.075
H.E.A.T. M310	M62	APG 474.1/67	Time	2	1.23	1000	.087
H.E.A.T. M66	M62	BRL 284 May 43	Resist.	2	0.75	775	.050
					0.98	991	.069
H.E.A.T. M66	M62	APG 471.822/1330	Resist.	2	0.98	1000	.070
H.E.A.T. M66	T93	APG 471.822/1330	Resist.	2	0.96	1000	.068
Chem. Mk 2	Round Wood Plug	BRL 284 June 42	Resist.	1	0.78	1095	.137
					1.24	1935	.307



12. 75mm Projectiles (Con.)

d. Stability

Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	n cal.	s	K_M
H.V.A.P. T45	Tracer	Memo May 45 APG 471.121/50	2890	2890	25.586	1.44	1.62
H.E. M48	M39A2	O.P. 4982	4	908	25	1.32	1.77
H.E. M48	M39A2	O.P. 4982	3	1117	25	1.19	1.90
H.E. M48	M39A2	O.P. 4982	5	1490	25	1.34	1.71
H.E. M48	M39A2	O.P. 4982	3	2184	25	1.34	1.77
H.E. M48	M43	O.P. 4982	4	905	25	1.30	1.90
H.E. M48	M43	O.P. 4982	4	1113	25	1.31	1.87
H.E. M48	M43	O.P. 4982	4	1479	25	1.34	1.86
H.E. M48	M43A3	BRLM 203	4	1950	22	1.84	1.71
H.E. M48	M43	O.P. 4982	4	2190	25	1.44	1.71
H.E. M48	M48	BRLM 203	4	1950	22	1.88	1.70
M48 empty	T81	BRLM 154	3	1870	25.586	1.45	
H.E.A.T. M66	M62	Memo Nov 44	4	1000	25.586	1.22	2.26
Chem. M64	M48	BRLM 99	5	1877	25.586	1.33	
Chem. M64	M48	Memo Nov 44	5	1000	25.586	1.26	1.93
Chem. T19[a]	M54	BRLM 38	3	1950	25.586	1.55	1.63
Chem. T19[b]	M54	BRLM 60	2	1500	25.586	1.01	
Chem. T19[c]	M54	BRLM 89	3	1500	25.586	1.46	

[a]Smoke pellets held in place, either with adhesive tape and cement or with extra spacers and emery paper (otherwise, large yaws were obtained).

[b]Revised 30 Apr 42; but chipboard tubes were left out and adapters were not staked. (The smoke pellets apparently did not attain their full spin.)

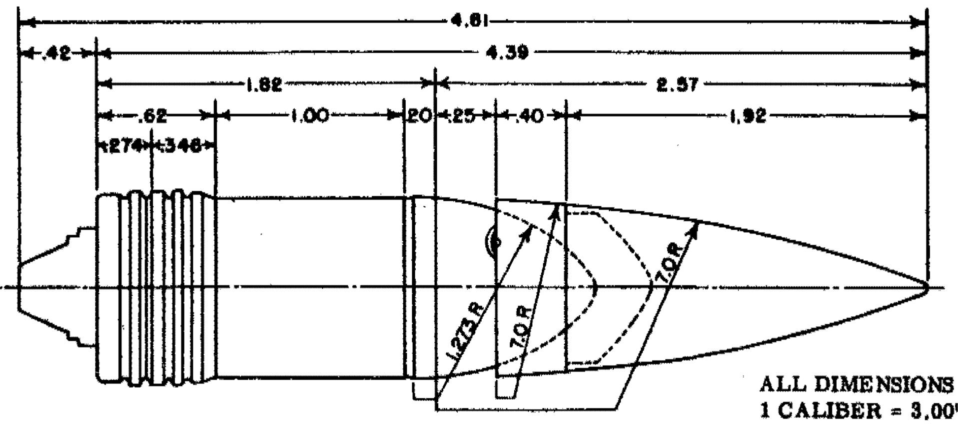
[c]Revised 30 Apr 42, with spacers replaced by pasteboard rings glued to each end of the metal smoke unit with a paper washer between them.

e. Spin

Shell	H.E. M48
Fuze	N.D.R.C.
s'/d^2	13.4
Report	BRLM 297
No. of Rounds	5
Gun	T13E1 (n=22)
Muzzle Velocity	2014 ft/sec.
Reynold's No.	2.30×10^6
K_A	0.005,87
C'_{DF}	0.001,75

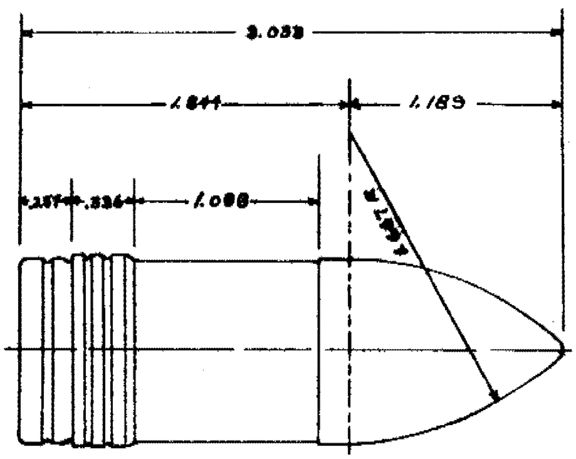
f. Pitch of Rifling of 75mm Guns (2.953")

Gun	n-cal.
Gun M1897 (French) and Modifications	25.586
Tank Guns M2, M3 and M6	25.586
Aircraft Guns M4 and M5 (T13E1)	25.586
Aircraft Guns M4 Modified, M5A1, and T13E1, Tubes No. 64609 and 64610	22
Antiaircraft Gun T6	25.586
Gun M1920 M VI No. 1	25
Rifle T21	22
Howitzers M1, M1A1, M2 and M3	20
Sub-caliber Guns M1916 M IIA1, M7, M8 M9 and M12	25.40



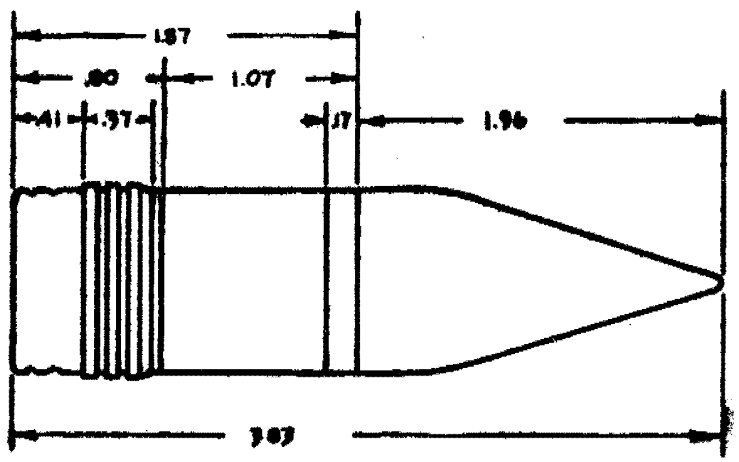
ALL DIMENSIONS IN CALIBERS
1 CALIBER = 3.00"

PROJECTILE, A.P.C., 3", M62; FUZE, B.D., M66A1

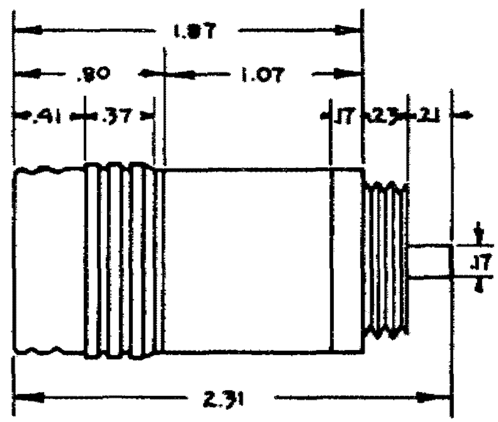


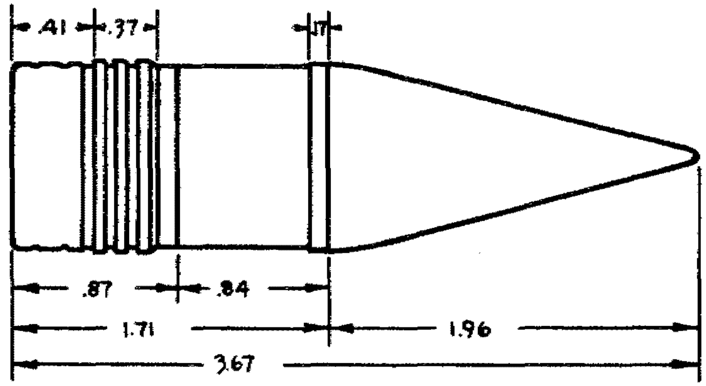
ALL MEASUREMENTS IN CALIBERS
1 CALIBER = 3.000"

SHOT, 3 IN., A.P., M79

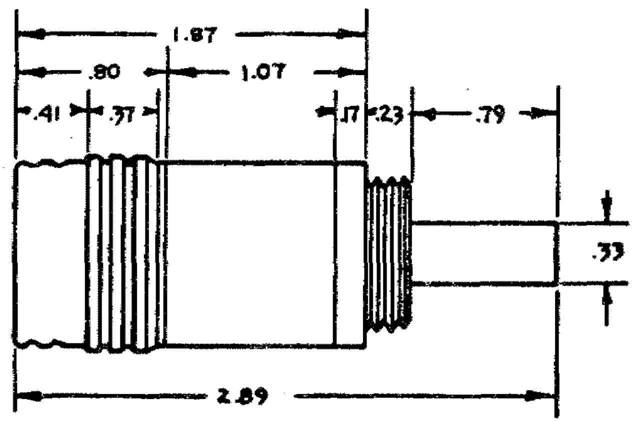


SHOT, H.V.A.P., 3-INCH, T4



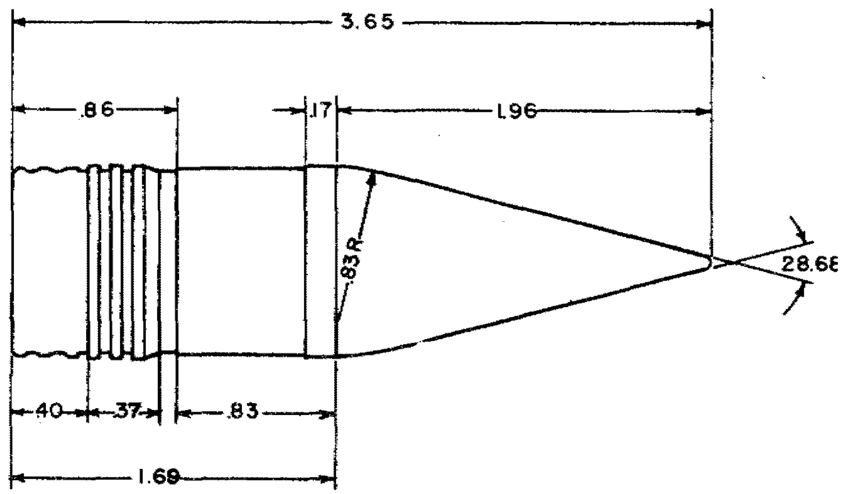


SHOT, H.V.A.P., 3-INCH, T4E1

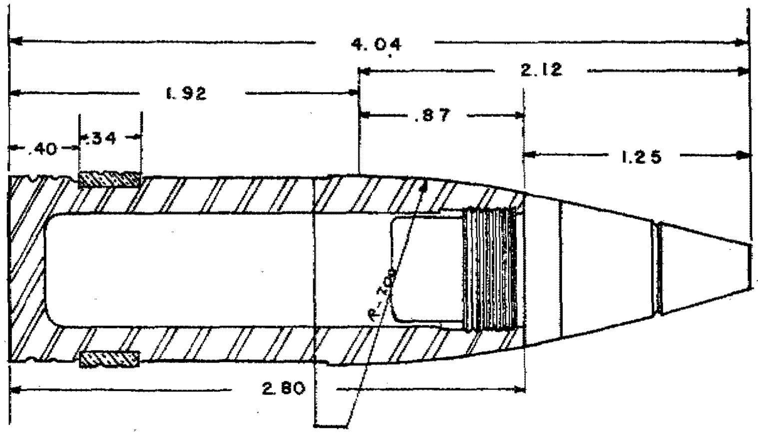


SHOT, H.V.A.P., 3-INCH, T4 WITHOUT WINDSHIELD WITH 1/2 INCH OR 1-INCH STEEL ROD PROTRUDING FROM NOSE

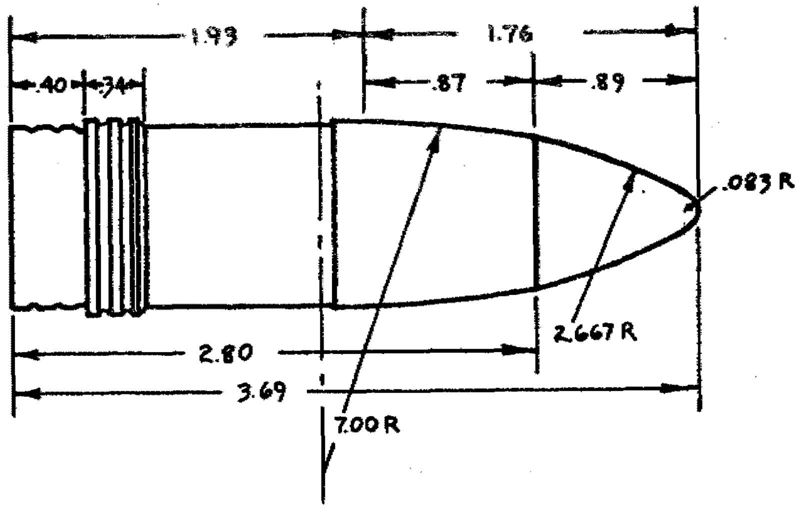
ALL DIMENSIONS IN CALIBERS



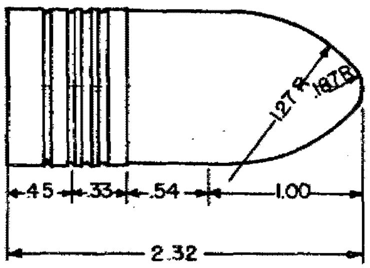
SHOT, H.V.A.P., 3-INCH, M93



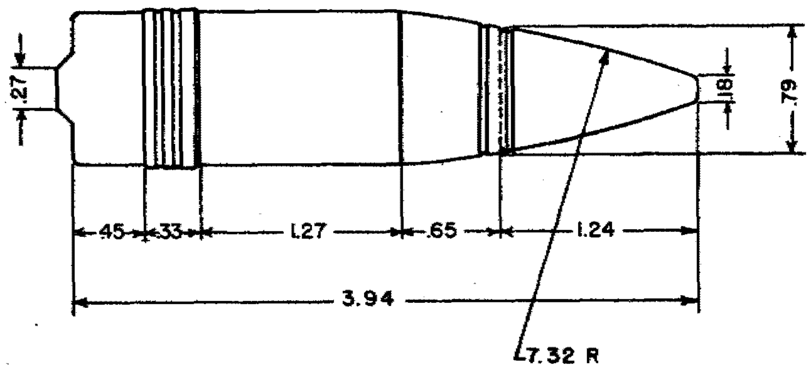
SHELL, H.E., 3-INCH, M42 WITH FUZE, M.T., M43



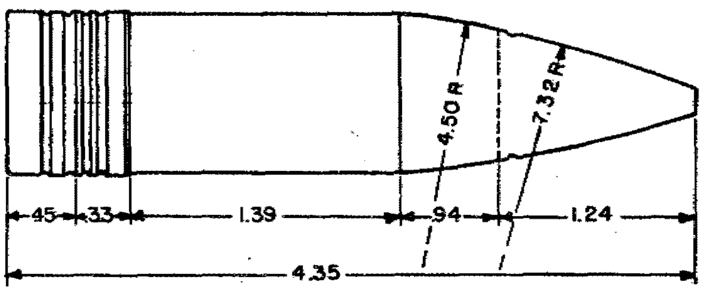
SHELL, H.E., 3-INCH, M42A1; FUZE, C.P., M78



PROJECTILE, A.P., 3-INCH, MARK 29 W/O WINDSHIELD OR CAP

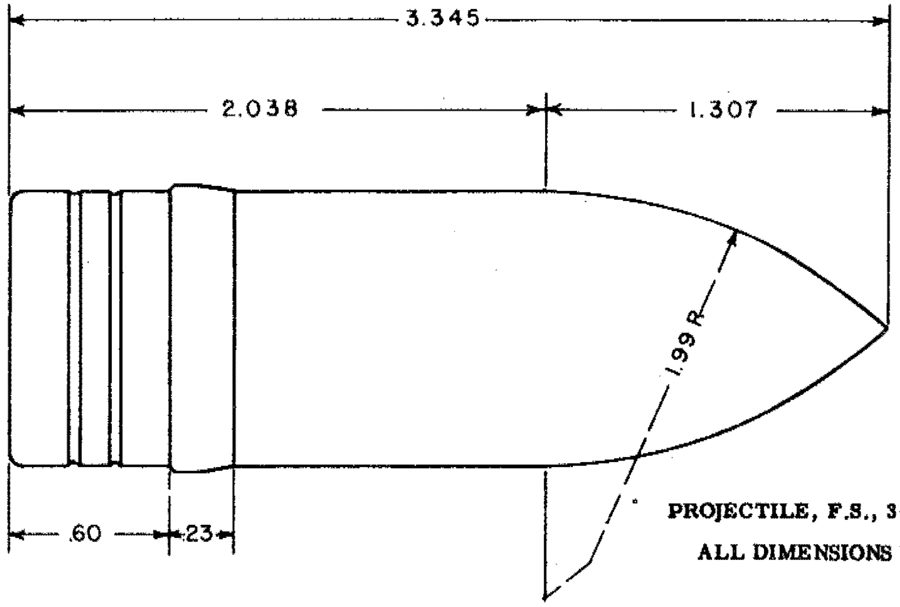


PROJECTILE, 3-INCH, MARK 27; DUMMY NOSE PLUG



PROJECTILE, ILLUMINATING, 3-INCH, MARK 25; DUMMY NOSE PLUG

ALL DIMENSIONS IN CALIBERS



PROJECTILE, F.S., 3-INCH, MARK 3
ALL DIMENSIONS IN CALIBERS

13. 3-inch Projectiles

a. Drawings

Projectile, Armor-piercing Capped, M62 and M62A1	75-2-292
Shot, Armor-piercing, M79	75-18-45
Shot, Armor-piercing Discarding-sabot, 76/48mm (APG Photo A8392)	
Shot, Hypervelocity Armor-piercing, T4	{TAM 960 Rev. 17 July 44}
Shot, Hypervelocity Armor-piercing, T4E1	TAM 1021
Shot, Hypervelocity Armor-piercing, T4E17, T4E18 and M93 (T4E20)	75-2-361 to 363
Shot, Hypervelocity Target Practice, T24E1 (same contour as H.V.A.P. M93)	
Shell, High Explosive, M42A1	75-18-33
Projectile, Mark 27 (with Dummy Nose Plug)	Fig. 17, NPG Report 3-45
Projectile, Illuminating, Mark 25 (with Dummy Nose Plug)	Fig. 22, NPG Report 3-45
Projectile, Armor-piercing, Mark 29, without windshield or cap	Fig. 24, NPG Report 3-45
Projectile, F.S., Mark 3	Naval Bureau of Ord. 54759
Fuze, Mechanical Time, M43 (T12)	73-7-29
Fuze, Point Detonating, M48 (T3)	73-2-140
Fuze, Concrete Piercing, M78 (T105 Type 6)	73-2-214
Fuze, Base Detonating, M66A1	73-2-178
Fuze, Experimental, National Defense Research Committee (same contour as M43 and M48 Fuzes)	

13. 3-inch Projectiles (Con.)

b. Physical Characteristics

Projectile	Fuze	Weight Lb. Std.	Weight Lb. Meas.	No. of Rounds	g cal.	A lb.ft.^{2}	B lb.ft.^{2}
A.P.C. M62A1	M66A1	15.40	15.44	2	1.403	0.1159	0.7593
A.P. M79	Tracer	15.00					
A.P.D.S. 76/48mm			7.56	1	2.416	2.16	13.39
H.V.A.P. T4	Tracer	9.53	9.49	6	1.129*	0.06021*	0.2970*
Same w/o windshield: with 1" rod			7.50	11			
Same w/o windshield: with 1/2" rod			9.52	11			
H.V.A.P. T4E1	Tracer	9.75			1.178*	0.05927*	0.3070*
H.V.A.P. T4E17	Tracer	9.31					
H.V.A.P. T4E18	Tracer		7.285	1	1.128	0.0395	0.172
H.V.A.P. M93	Tracer	9.31	9.47	4			
H.V.T.P. T24	Tracer		9.23	4			
H.V.T.P. T24E1	Tracer	9.31	9.31	2	1.118	0.0607	0.253
H.E. M42	M43	12.80	13.05	14	1.540	0.1105	0.8092
H.E. M42A1	M78	13.52	13.47	5	1.546	0.1098	0.8106
F.S. Mk 3	Base	13.00			1.412*	0.1091*	0.6580*

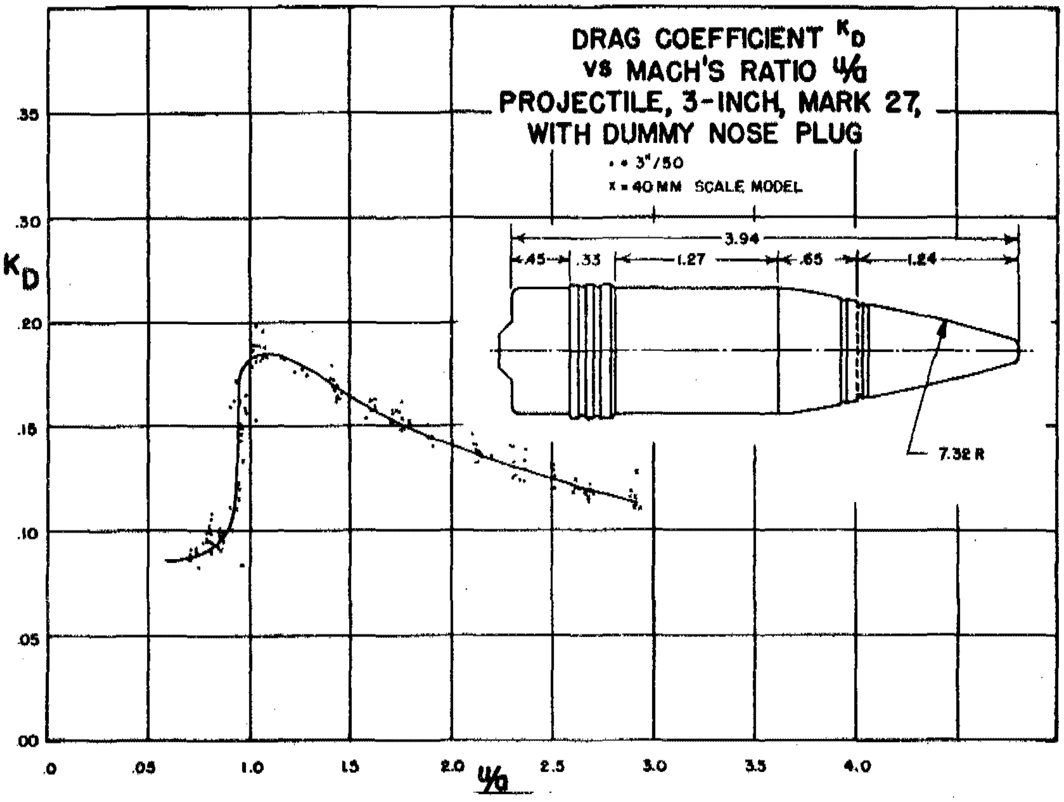
*Computed from dimensions on drawings.

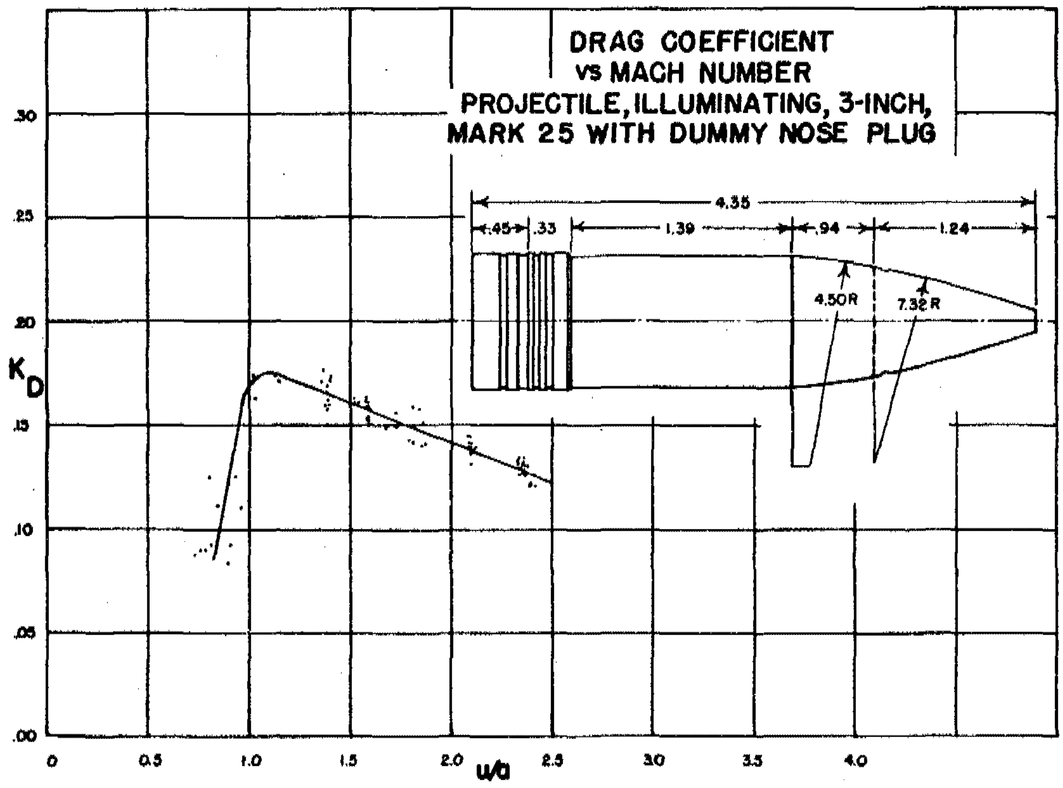
13. 3-inch Projectiles (Con.)

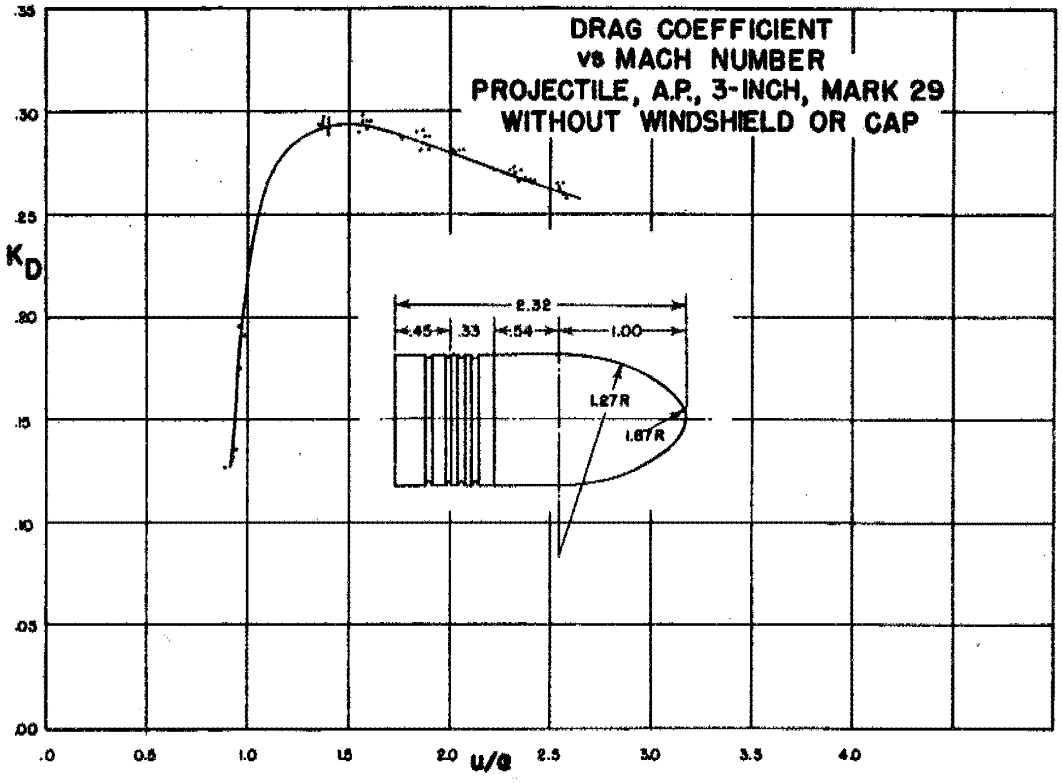
c. Drag

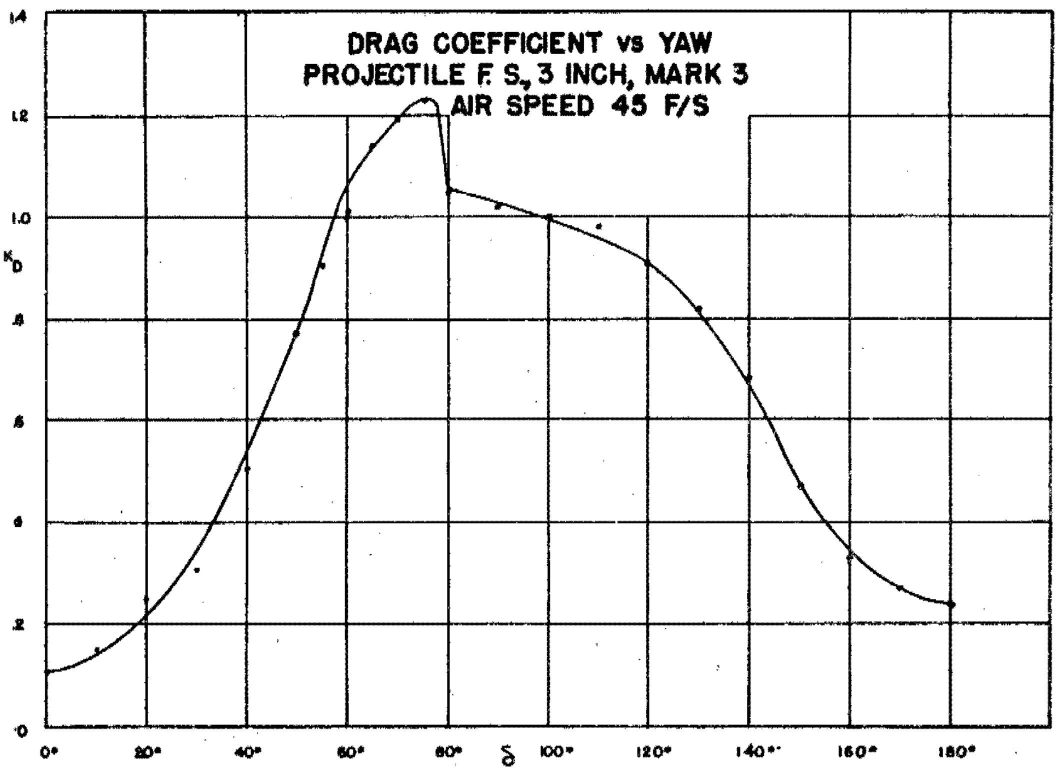
Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
A.P.C. M62	M66A1	K-I-9 May 43 Memo Mar 43 Memo Oct 44	Resist.	6	1.05	2565 1958 2812	.131 .159 .119
A.P. M79	Tracer	K-I-9 Aug 42	Resist.	1	1.05	2533	.232
A.P.D.S. 76/48mm		Memo Sep 44	Resist.	8	1.31	3520	.121
H.V.A.P. T4	Tracer	BRLM 317	Resist.	2	1.22	3320	.115
Same w/o windshield: with 1" rod		Memo Oct 44	Resist.	1	1.01	3742	.201
Same w/o windshield: with 1/2" rod		Memo Oct 44	Resist.	1	2.22	3293	.449
H.V.A.P. T4E1	Tracer	BRLM 335	Resist.	8	1.09	3266	.106
H.V.A.P. T4E17	Tracer	Memo Oct 44	Resist.	8	1.175	3337	.112
H.V.A.P. M93	None	APG 471/1440-57	Time	8	1.15	3031	.117
H.V.A.P. M93	Tracer	APG 471/1440-79	Time	8	1.165	3087	.119
H.V.T.P. T24	Tracer	APG 471/1440-79	Time	8	1.153	3078	.118
H.V.T.P. T24E1	Tracer	APG 471/1440-57	Time	8	1.12	3048	.113
H.V.T.P. T24E1	Tracer	APG 471/1440-79	Time	8	1.145	3082	.117
H.E. M42	Adapter Mk II, Wood Plug	BRL 284	Resist.	1	1.16	2800	.246
H.E. M42	Large Wood Plug	BRL 284	Resist.	1	2.12	2800	.449
H.E. M42A1	M78	BRL 298	Resist.	6	1.37	2569	.170
Mk 27	Dummy	NPG 3-45	Resist.			See graph	
Illum Mk 25	Dummy	NPG 3-45	Resist.			See graph	
A.P. Mk 29 w/o windshield or cap		NPG 3-45	Resist.			See graph	
F.S. Mk 3	Base	BRL 261 NPG S-72-4 (49)	Air-stream* Under-water Traj.			See graphs	

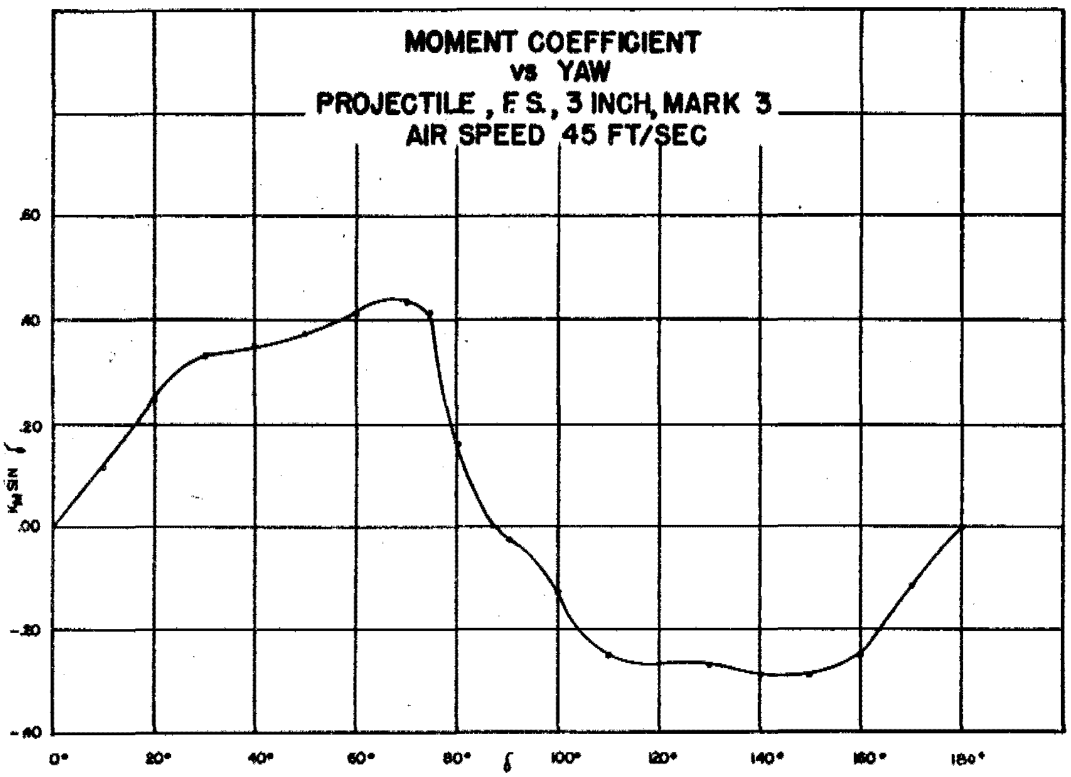
*Measurements of the drag, torque and cross wind force were made with a wooden model of this projectile in the same way as with the 6" Common Projectile (see par. 18 c). The yaw-drag coefficient of the 3" Projectile, valid for yaws from 0 to 55°, is 0.00250 per deg^2.

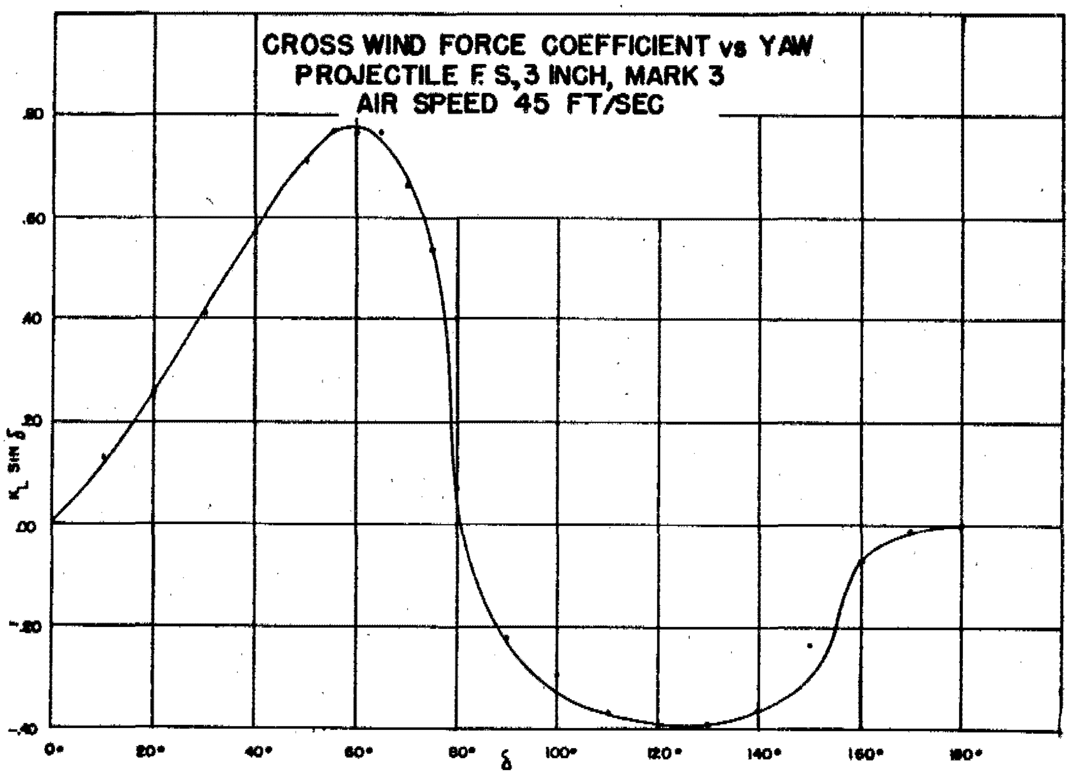

DRAG COEFFICIENT K_D
VS MACH'S RATIO u/a
PROJECTILE, 3-INCH, MARK 27, WITH DUMMY NOSE PLUG
• = 3"/50
x = 40 MM SCALE MODEL
3.94
.45
.33
1.27
.65
1.24
7.32 R
K_D
.35
.30
.20
.15
.10
.05
.00
.0
.05
1.0
1.5
2.0
2.5
3.0
3.5
4.0
u/a


DRAG COEFFICIENT
VS MACH NUMBER
PROJECTILE, ILLUMINATING, 3-INCH, MARK 25 WITH DUMMY NOSE PLUG
4.35
.45
.33
1.39
.94
1.24
4.50R
7.32R
K_D
.30
.25
.20
.15
.10
.05
.00
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
u/a


DRAG COEFFICIENT
vs MACH NUMBER
PROJECTILE, A.P., 3-INCH, MARK 29
WITHOUT WINDSHIELD OR CAP
K_D
u/a
2.32
.45
.33
.54
1.00
1.27R
1.67R


DRAG COEFFICIENT vs YAW
PROJECTILE F. S., 3 INCH, MARK 3
AIR SPEED 45 F/S
K_D
δ


MOMENT COEFFICIENT
vs YAW
PROJECTILE, F. S., 3 INCH, MARK 3
AIR SPEED 45 FT/SEC
$K_M \sin \delta$
.60
.40
.20
.00
-.20
-.40
0°
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°


CROSS WIND FORCE COEFFICIENT vs YAW
PROJECTILE F. S., 3 INCH, MARK 3
AIR SPEED 45 FT/SEC
$K_L \sin \delta$
.80
.60
.40
.20
.00
-.20
-.40
0°
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°

13. 3-inch Projectiles (Con.)

d. Stability

Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	$\frac{n}{cal.}$	s	K_M
A.P.C. M62A1	M66A1	Memo Oct 45	2	2460	40	1.05	1.44
A.P.D.S. 76/48mm		Memo Nov 44	1	3500	32	1.4-2.0	.77 / -.60
H.V.A.P. T4	Tracer	BRLM 317	7	3400	40	1.07	2.45
H.V.A.P. T4E1	Tracer	BRLM 335	8	3400	40	1.25	0.77
H.V.A.P. T4E17	Tracer		9	3440	40	1.44	
H.V.T.P. T24	Tracer	APG 471/1440-79		3420	40	2.32	0.925
H.V.T.P. T24E1	Tracer	APG 471/1440-57		3300	40	1.3	0.94
H.E. M42	M43	O.P. 4684	2	2800	40	1.30	0.99
H.E. M42B2	M48	BRLM 293	6	1800	40	1.39	0.91
H.E. M42A1	M48	BRLM 293	6	1550	40	1.45	0.88
H.E. M42A1	M78	BRLM 298	4	2600	40	1.57	0.79
F.S. Mk 3	Base	BRL 261	See par. 13c and graph				

e. Spin

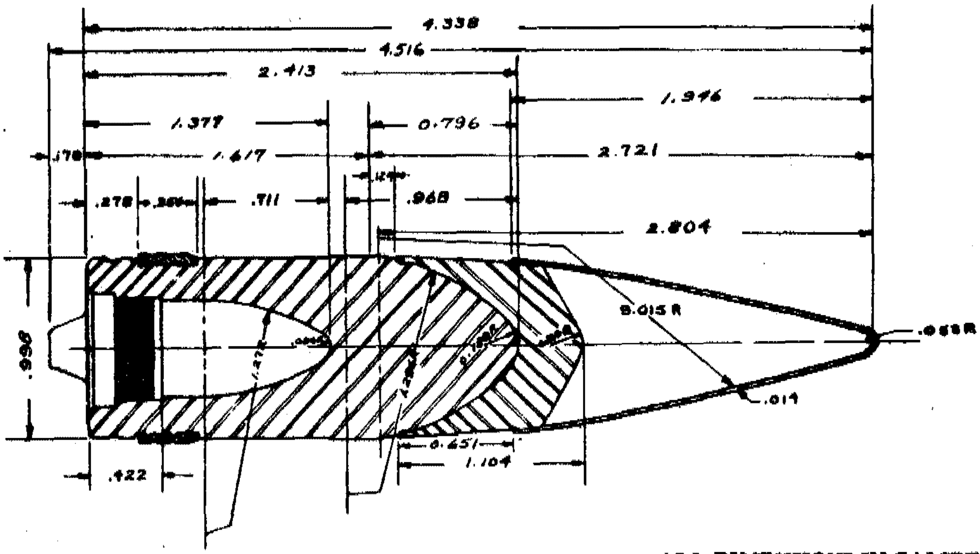
Shell	H.E. M42
Fuze	N.D.R.C.
S'/d^2	10.7
Report	BRL 408
No. of Rds.	4
Gun	3" M3 (n = 40)
Muzzle Velocity	2800 ft/sec
Reynold's No.	2.75×10^6
K_A	0.005,85
C'_{DF}	0.002,18

f. Pitch of Rifling of 3-inch and 76mm Guns

(The caliber of all these guns is 3.000 inches)

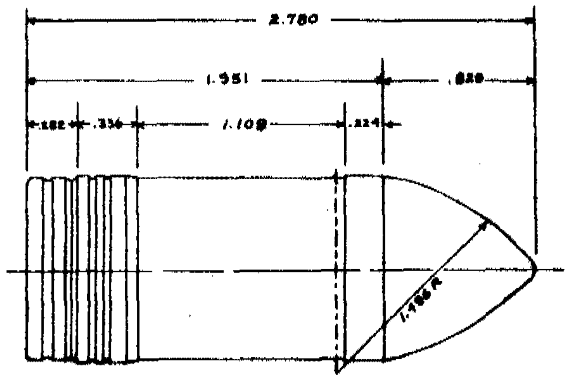
Guns	n-cal.
3" Antiaircraft Guns M1917 and modifications*, M1918 and modifications*, M1925M1, M1, M2, M3 and M4	40
3" 15-pounder Guns M1902 and M1903	25
3" Antitank Gun M5	40
3" Tank Guns M6 and M7	40
76mm Tank Guns M1 and M1A1	40
76mm Tank Gun M1A2	32

*Some Guns of these models were originally rifled with a pitch of 25 calibers.



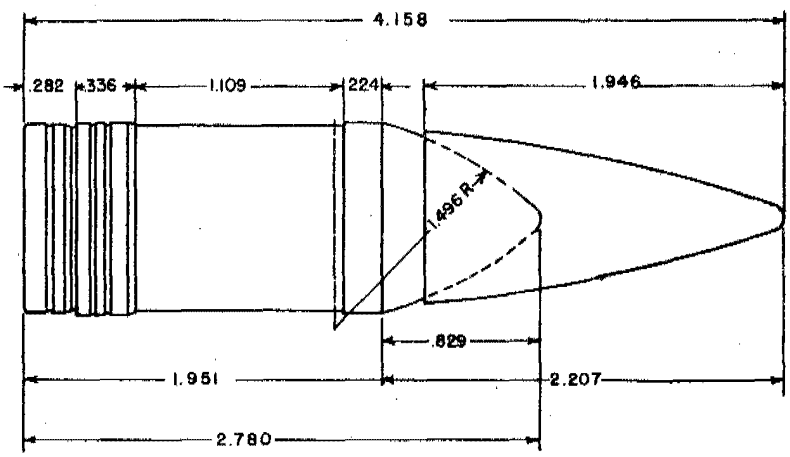
PROJECTILE, A.P.C., 90MM, M82; FUZE, B.D., M68

ALL DIMENSIONS IN CALIBERS
1 CALIBER = 3.543"

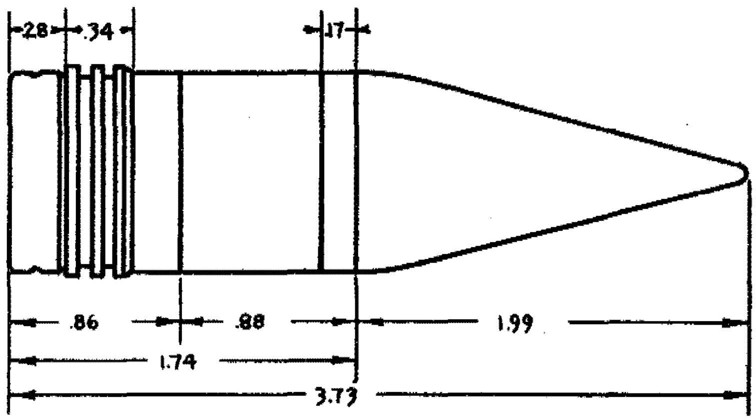


SHOT, A.P., 90MM, M77

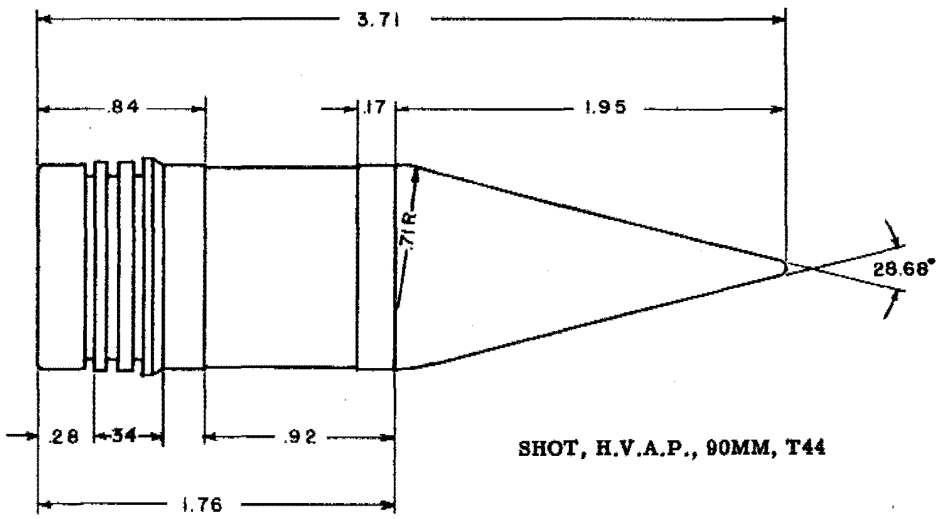
ALL MEASUREMENT IN CALIBERS
1 CALIBER = 3.543"



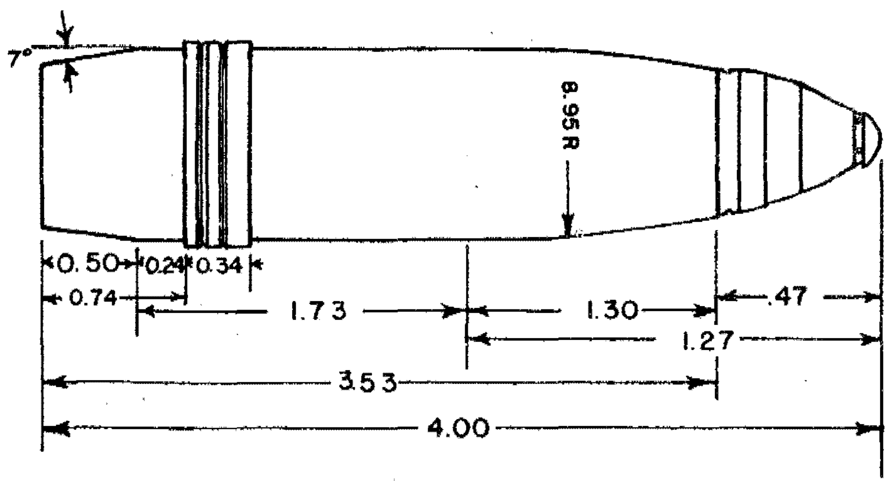
SHOT, A.P., 90MM, T33



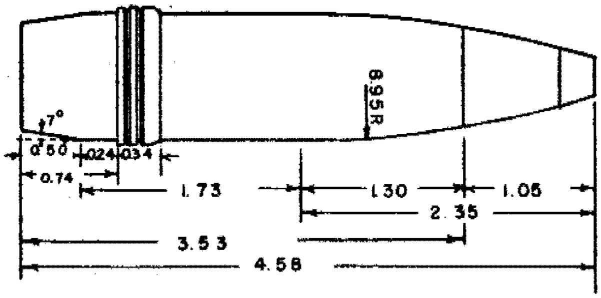
SHOT, H.V.A.P., 90MM, T30E11, T30E12, AND T30E15



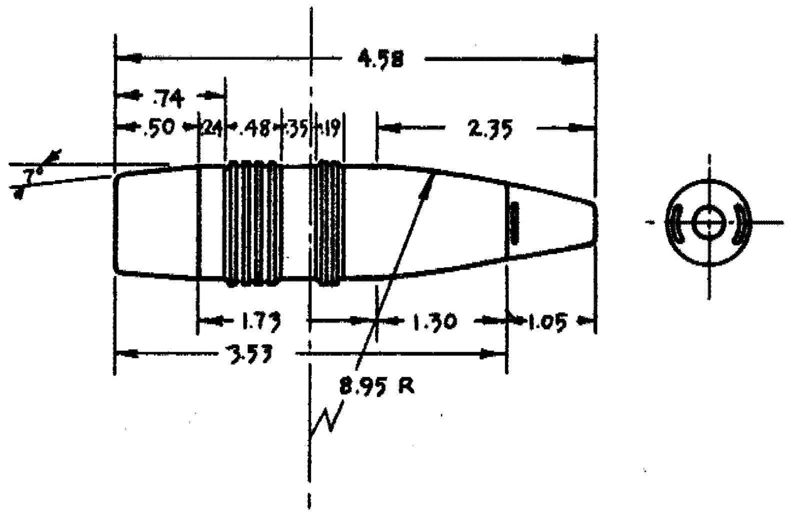
SHOT, H.V.A.P., 90MM, T44



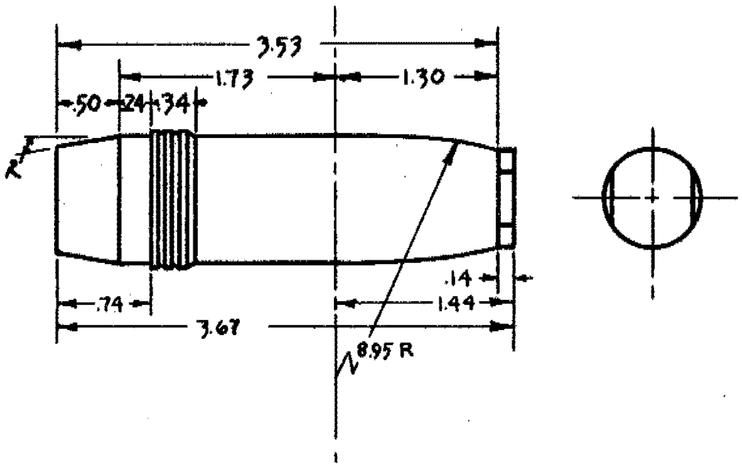
SHELL, H.E., 90MM, M71; FUZE, 21-SEC. A.A., MK III



SHELL, H.E., 90MM, M71; FUZE, M.T., M43



SHELL, H.E., 90MM, T15; FUZE, DUMMY, M44A2



SHELL, H.E., 90MM, M58; PLUG, CLOSING, 75-14-309E

14. 90mm Projectiles

a. Drawings

Projectile, Armor-piercing Capped, M82	75-18-46, 47 and 51
Shot, Armor-piercing, M77	75-18-44
Shot, Armor-piercing, T33	75-2-388
Shot, Hypervelocity Armor-piercing, T30E11	
Shot, Hypervelocity Armor-piercing, T30E12	
Shot, Hypervelocity Armor-piercing, T30E14 (Approximately the same contour as T30E15)	
Shot, Hypervelocity Armor-piercing, T30E15	TAM 1238
Shot, Hypervelocity Armor-piercing, M304 (T30E16) (Approximately the same contour as T30E15)	75-1-234
Shot, Hypervelocity Armor-piercing, T38E5 (2.215-inch shot with sabot)	
Shot, Hypervelocity Armor-piercing, T44	75-2-384 & 385 75-14-538
Shot, Hypervelocity Target Practice, T45 (Same contour as H.V.A.P. M304)	
Shell, High Explosive, M58 (T3) (Same contour as H.E. M71)	75-18-39
Shell, High Explosive, M71 (T8)	75-18-42
Shell, High Explosive, T15	TAM 20
Fuze, Base Detonating, M68	73-2-181 and 182
Fuze, Mechanical Time, M43, M43A1, M43A2, and M43A3	73-7-29
Fuze, Point Detonating, M48	73-2-140
Fuze, 21-second Antiaircraft, Mark III	73-3-111
Fuze, Dummy, M44A2	72-5-2
Fuze, Experimental, National Defense Research Committee (Same contour as M43 and M48 Fuzes)	
Plug, Closing	75-14-309E

14. 90mm Projectiles (Con.)

b. Physical Characteristics

Projectile	Fuze	Weight Lb. Std	Weight Lb. Meas	No. of Rounds	g cal	A lb.ft.^{2}	B lb.ft.^{2}
A.P.C. M82	M68	24.11	24.12	20			
A.P. M77	Tracer	23.40	23.27	10			
A.P. T33	Tracer	24.06	24.01	5	1.241	0.2475	1.329
H.V.A.P. T30E11	Tracer		14.48	4			
H.V.A.P. T30E12	Tracer		17.38	1	1.205	0.1510	0.795
H.V.A.P. T30E14			15.5				
H.V.A.P. T30E15	Tracer		16.62	1	1.168	0.1390	0.652
H.V.A.P. M304	Tracer	16.80	16.78	7			
H.V.A.P. T38E5	Tracer		8.29*	1	1.490*	0.0286*	0.1526*
H.V.A.P. T44	Tracer		16.78	8			
H.V.T.P. T45	Tracer		16.80	6	1.142	0.1961	0.6547
H.E. M58	M43	21.00	20.61		1.789	0.2528	2.499
H.E. M58	M48	21.00	20.65	10	1.785	0.2528	2.472
H.E. M71	Mk. III	23.40					
H.E. M71	M43	23.40	23.19	6	1.742	0.2753	2.627
Inert M71	M43		23.19	10	1.736	0.2751	2.611
H.E. T15	M44A2	23.5	23.5	6			

*These values pertain to a projectile without the sabot, as in flight. The base diameter was 2.210 in. The body diameter was 2.199 in. The caliber is considered 2.215 in.

14. 90mm Projectiles (Con.)

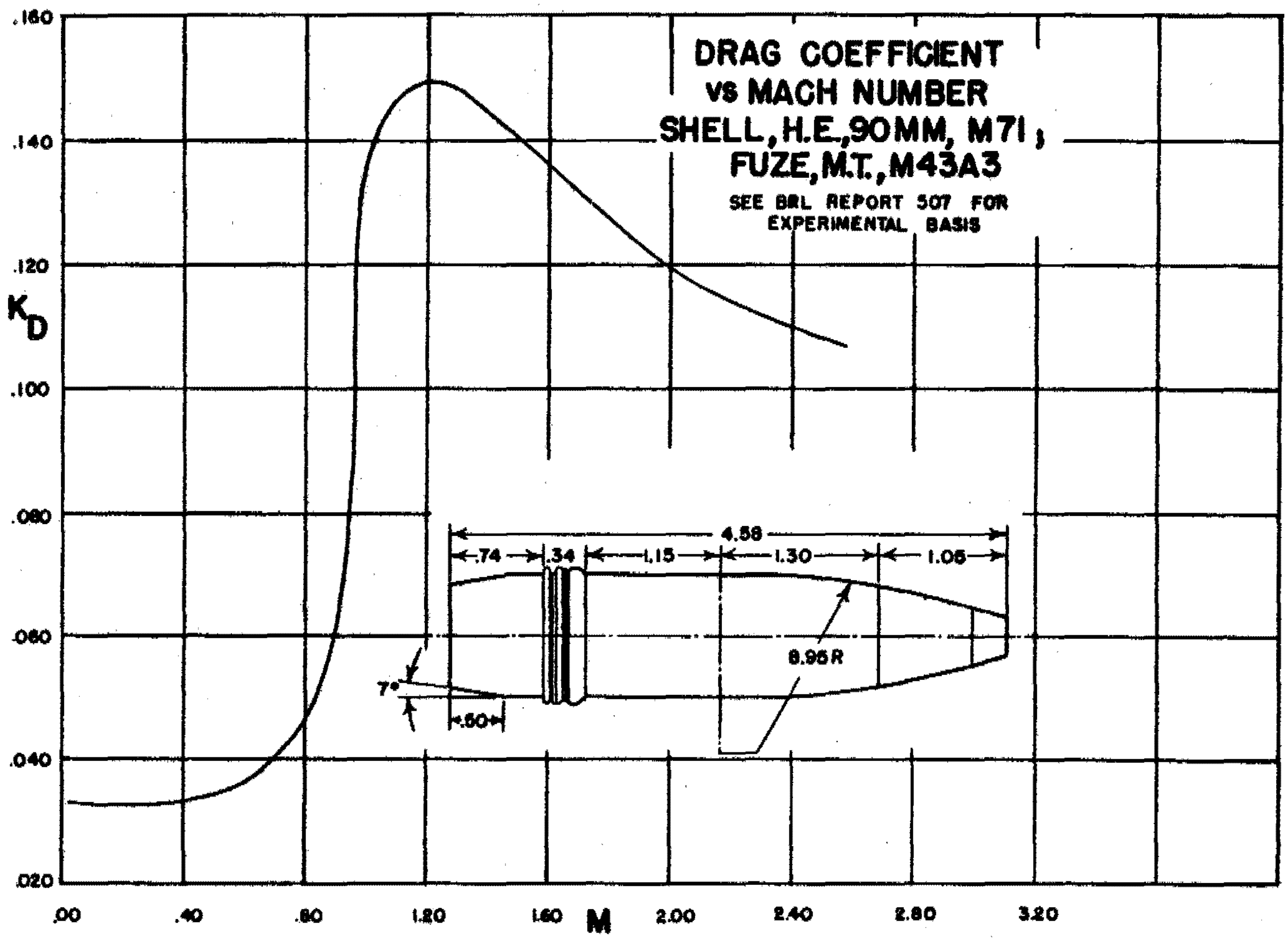
c. Drag

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
A.P.C. M82	M68	BRL 284 May 43 / Memo May 43	Resist.	6	.90	2000 / 2650	.135 / .109
A.P.C. M82	M68	Memo Aug 44	Resist.	6	.91 / .97	2640 / 2820	.110 / .110
A.P.C. M82	M68	MR347D Jan 45	Resist.	7	1.05	3017	.107
A.P.C. M82	M68	MR347D Jan 45	Time	7	.97	3240	.095
A.P. M77	Tracer	Memo Oct 42	Resist.	1	1.19	2587	.260
A.P. M77	Tracer	Memo Aug 44	Resist.	1	1.25	2621	.272
A.P. T33	Tracer	Memo Aug 44	Resist.	6	1.01	2666	.121
A.P. T33	Tracer	MR347D Jan 45	Resist.	7	1.06	3029	.108
A.P. T33	Tracer	APG 471.9/13-5168	Time	7	.965	2603	.106
A.P. T33	Inert Tracer	APG 471.9/13-5168	Time	7	.98	2598	.108
A.P. T33 w/o plug	None	APG 471.9/13-5168	Time	7	1.00	2595	.110
H.V.A.P. T30E11	Tracer	Memo Dec 44	Resist.	8	1.60*	3556	.146
H.V.A.P. T30E12	Tracer	Memo Dec 44	Resist.	8	1.25		
H.V.A.P. T30E14		Memo Dec 44	Resist.	8	1.52	3430	.143
H.V.A.P. T30E15	Tracer	MR347D Jan 45	Resist.	7	1.23 / 1.28	3316 / 3671	.118 / .114
H.V.A.P. M304	Tracer	APG 471.91/1	Time	8	1.16	3262	
H.V.A.P. T38E5	Tracer	Memo Jan 45	Resist.	7	2.20** / 1.48**	3628 / 2607	.198 / .162
H.V.A.P. T44	Tracer	Memo May 45	Resist.	8	1.32	3700	.117
H.V.T.P. T45	Tracer	APG 471.91/1	Time	8	1.16	3257	.114
H.E. M58	Plug, Closing	BRL 284 Nov 42	Resist.	5	2.35	2628	.324
H.E. M71	Mk III	BRL 284 May 43 / Memo May 43	Resist.	5	1.32	2200 / 2700	.203 / .180
H.E. M71	M43A3	BRL 507	Range			See graph	
H.E. T15	M44A2	K-I-9 Mar 44	Resist.	7	1.38	3340	.132

*The drag of the T30E11 Shot was probably increased by rough contours and large yaws.

**The T38E5 Shot may have had large yaws: only 2 rounds were fired at each velocity. A form factor of 1.51 was obtained from range firings.

14. **90mm Projectiles (Con.)**



d. Stability

Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	n cal	s	K_M
A.P. T33	Tracer	BRLM 336	6	2700	32	2.12	1.24
H.V.A.P. T30E12	Tracer	Memo Dec 44	6	3300	32	1.30	1.32
H.V.A.P. T30E15		MR347D Jan 45	2	3325	32	1.7	1.0
H.V.A.P. T38E5	Tracer	Memo Jan 45	2	3700	32	1.51	0.85
H.V.T.P. T45	Tracer	APG 471.91/1	6	3330	32	3.95	0.26
H.E. M58	M48	BRL 150	6	1920	20	2.72	1.39
H.E. M58	M48	BRL 165	8	2800	30	1.52	1.11
H.E. M71	M43	BRL 236	9	2705 (M=2.385)	32	1.32	1.25

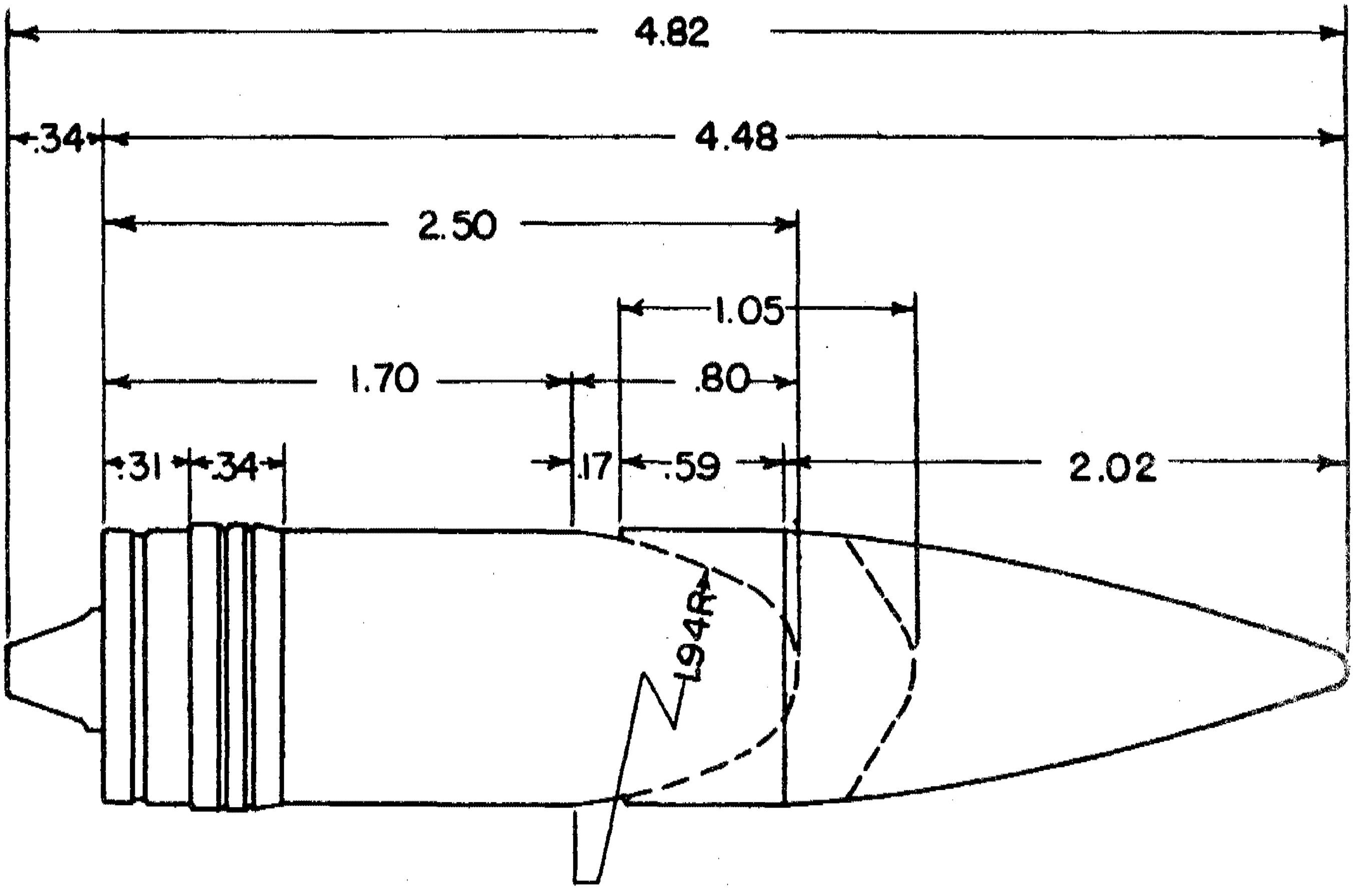
14. 90mm Projectiles (Con.)

e. Spin

Shell	H.E. M71
Fuze	N.D.R.C.
S'/d^2	11.9
Report	BRL 408
No. of Rds.	4
Gun	M1 (n = 32)
Muzzle Velocity	2700 ft/sec
Reynold's No.	2.95×10^6
K_A	0.0059
C'_{DF}	0.00198

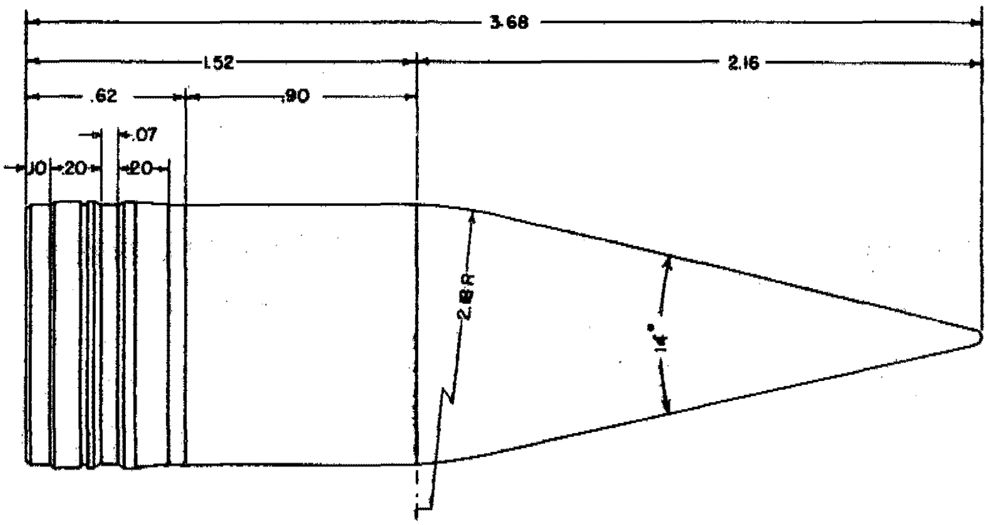
f. Pitch of Rifling of 90mm Guns (3.543")

Gun	n-cal
Gun T1	20
A.A. Gun T2	30
A.A. Guns M1, M1A1 and M2	32
Gun M3	32



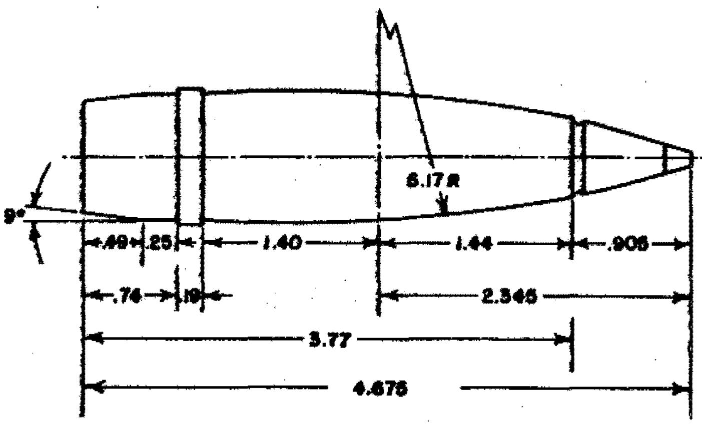
SHOT, A.P.C., 105MM, T13E2; FUZE, B.D., M66A1

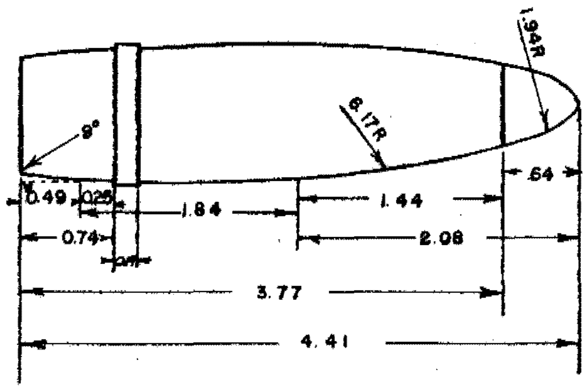
ALL DIMENSIONS IN CALIBERS



SHOT, H.V.A.P., 105MM, T29E4

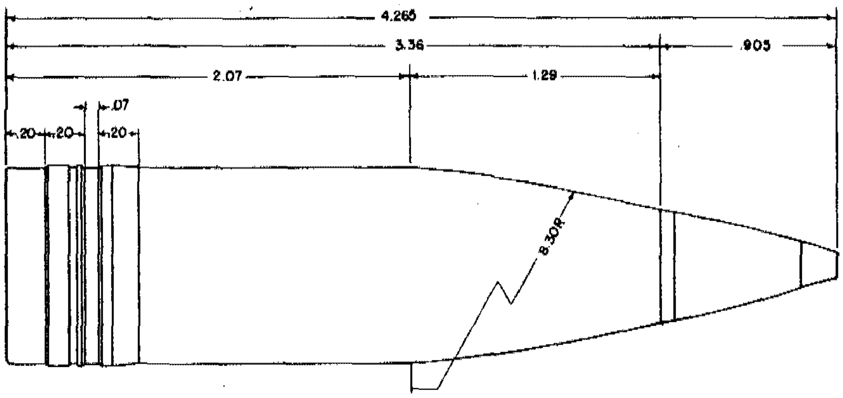
SHELL, H.E., 105MM, M1; FUZE, P.D., M48



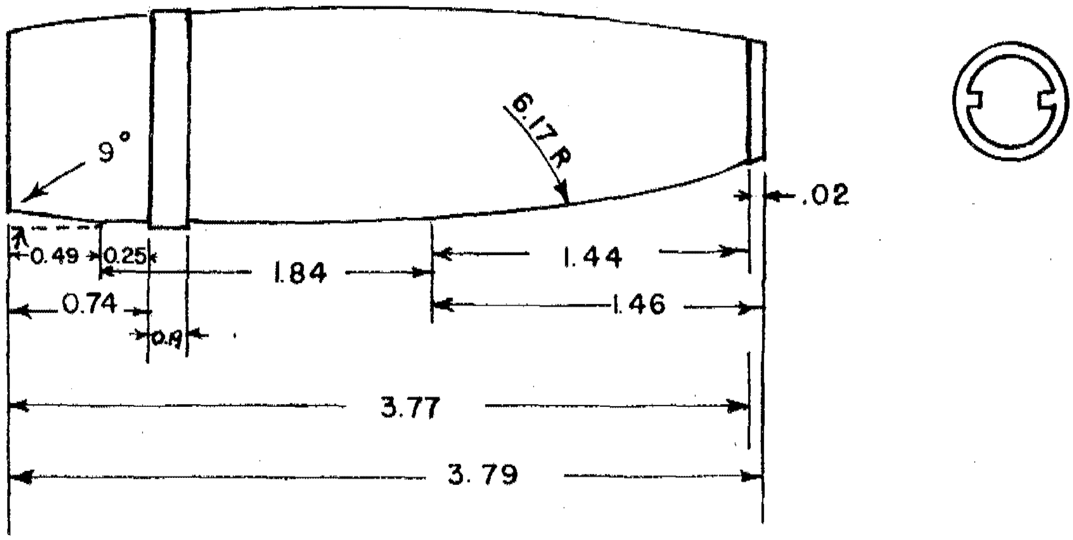


SHELL, H.E., 105MM, M1; FUZE, C.P., M78

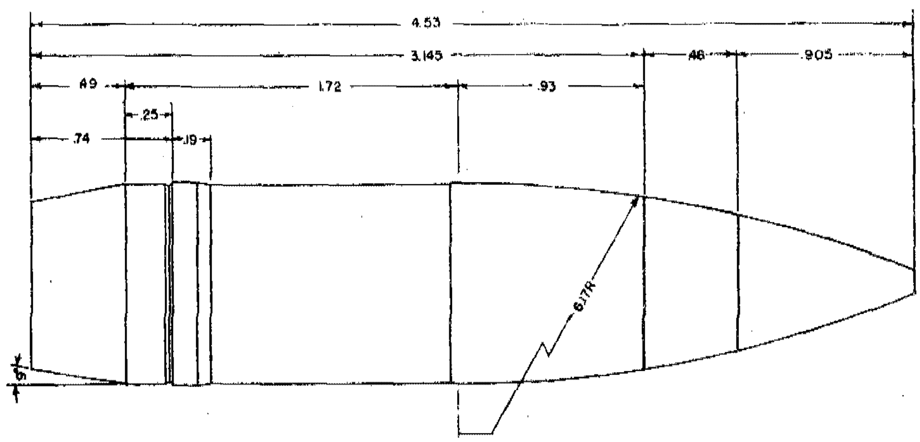
ALL DIMENSIONS IN CALIBERS



SHELL, H.E., 105MM, T30E1; FUZE, P.D., M51A4

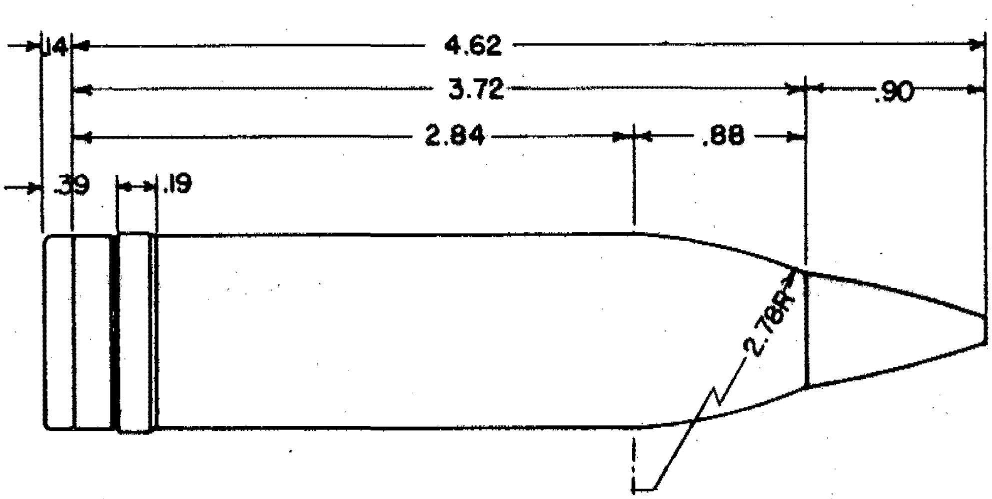


SHELL, H.E., 105MM, M1; CIRCULAR PLUG

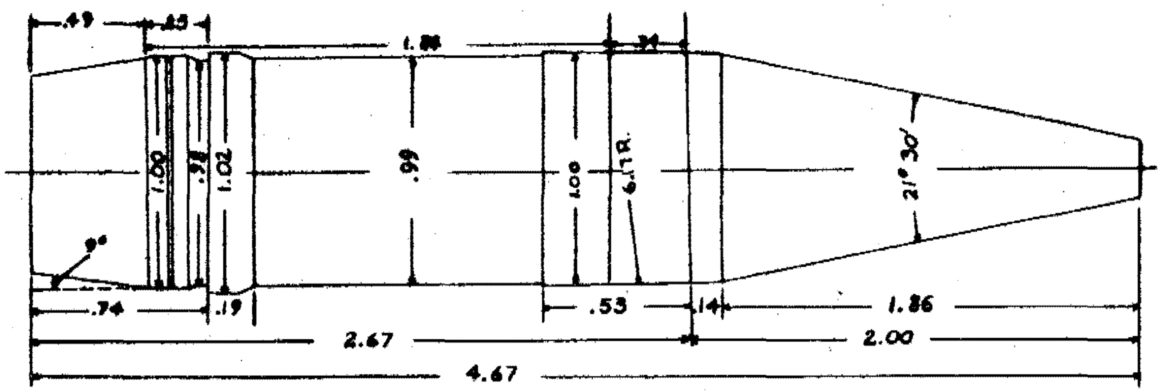


SHELL, SMOKE (B.E.), 105MM, M84; FUZE, T. SQ. M54

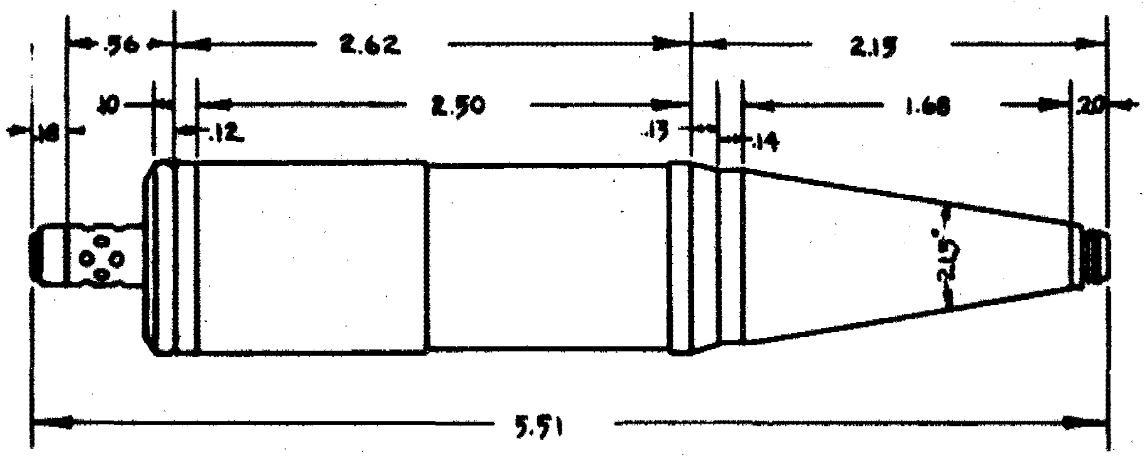
ALL DIMENSIONS IN CALIBERS



SHELL, ILLUMINATING, 105MM, M314; FUZE, T. SQ. M54



SHELL, H.E.A.T., 105MM, M67



SHELL, H.E.A.T., E81, FOR 4.2 INCH CHEMICAL MORTAR; FUZE, B. D., M62A1, MODIFIED

ALL DIMENSIONS IN CALIBERS

15. 105mm and 4.2-inch Projectiles

a. Drawings

Shot, Armor-piercing Capped, T13E2	Bethlehem Steel Co. 14017A
Shot, Hypervelocity Armor-piercing, T29E4	75-4-149, 150 & 151
Shell, High Explosive, M1	75-4-75
Shell, High Explosive, T30E1	75-4-153
Shell, High Explosive Antitank, M67	75-14-352, 75-4-106 and 107
Shell, High Explosive Antitank, M67E1 (Same contour as M67)	
Shell, Chemical, M60 (Same contour as H.E. Shell M1)	75-4-91
Shell, Smoke (BE), M84	75-4-105
Shell, Illuminating (BE), M314 (T16) (Contour similar to Smoke Shell M84)	75-1-229
Fuze, Point Detonating, M48	73-2-140
Fuze, Point Detonating, M51A4	73-2-145
Fuze, Time and Superquick, M54	73-3-154
Fuze, Dummy, M59 (same contour and weight as M48)	72-5-5
Fuze, Concrete Piercing, M78 (T105 Type 6)	73-2-214
Fuze, Base Detonating, M62	73-2-168
Fuze, Base Detonating, M66A1	73-2-178
Fuze, Dummy, T121 (base plug with red tracer)	

Shell, High Explosive Antitank, E81 (4.2" Chem. Mortar):

Design Study	TAM 1759
Ogive, Union and Cone	75-4-107
Body	C8-13-190 (CWS)
Cartridge container	E111-6-4 (CWS)
Striker nut	E111-6-5 & 6 (CWS)
Pressure Plate	E16-13-11 (CWS)
Rotating Disc	E16-13-29 (CWS)
Driver E21R1 (Comes off in bore)	B111-8-3 (CWS)

b. Physical Characteristics

Projectile	Fuze	Weight Lb. Std	Weight Lb. Meas	No. of Rounds	g cal.	A $lb.ft.^2$	B $lb.ft.^2$
A.P.C. T13E2	M66A1	41.00	40.99	6	1.442	0.611	3.88
H.V.A.P. T29E4	Tracer	24.60	24.60	5	1.180	0.286	1.416
H.E. M1	M54	33.00	33.00	1	1.739	0.554	5.345
H.E. M1	M59	33.00	32.87	5	1.749	0.5506	5.399
H.E. M1	M78	33.72	33.82				

15. 105mm and 4.2-inch Projectiles (Con.)

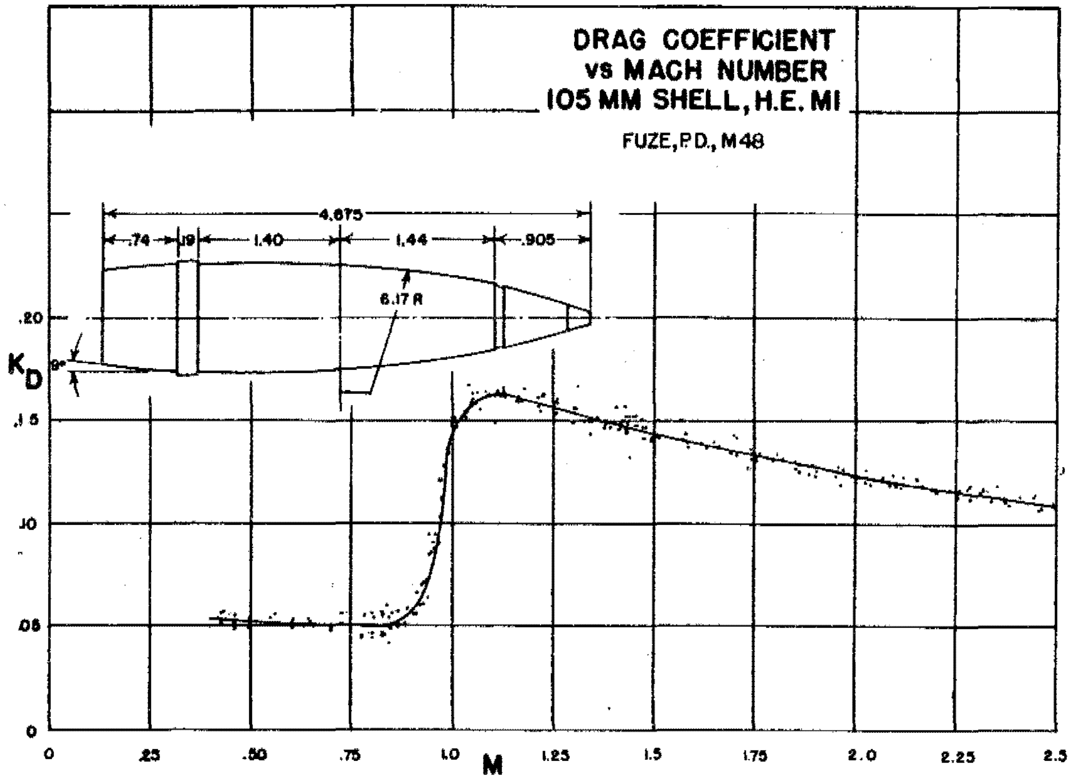
Projectile	Fuze	Weight Lb. Std.	Weight Lb. Meas.	No. of Rounds	g cal.	A lb.ft.^{2}	B lb.ft.^{2}
H.E.A.T. M67	M62	29.22	28.88	4	1.495	0.5085	4.106
H.E.A.T. M67E1	M62A1		29.04	3	1.486	0.5112	4.123
H.E.A.T. M67	T93		29.23				
Inert loaded (practice) M67	T121		29.00	5	1.492	0.513	4.168
H.E.A.T. E81	M62A1 Mod.		24.24	2	1.575*	0.4278	4.985
Chem. (WP) M60	M48	34.31	33.82	3	1.707	0.556	5.565
Smoke (BE) M84	M54	32.87	32.08	3	1.697	0.529	4.33
Illuminating (BE) M314	M54		36.46	3	1.824	0.631	5.47

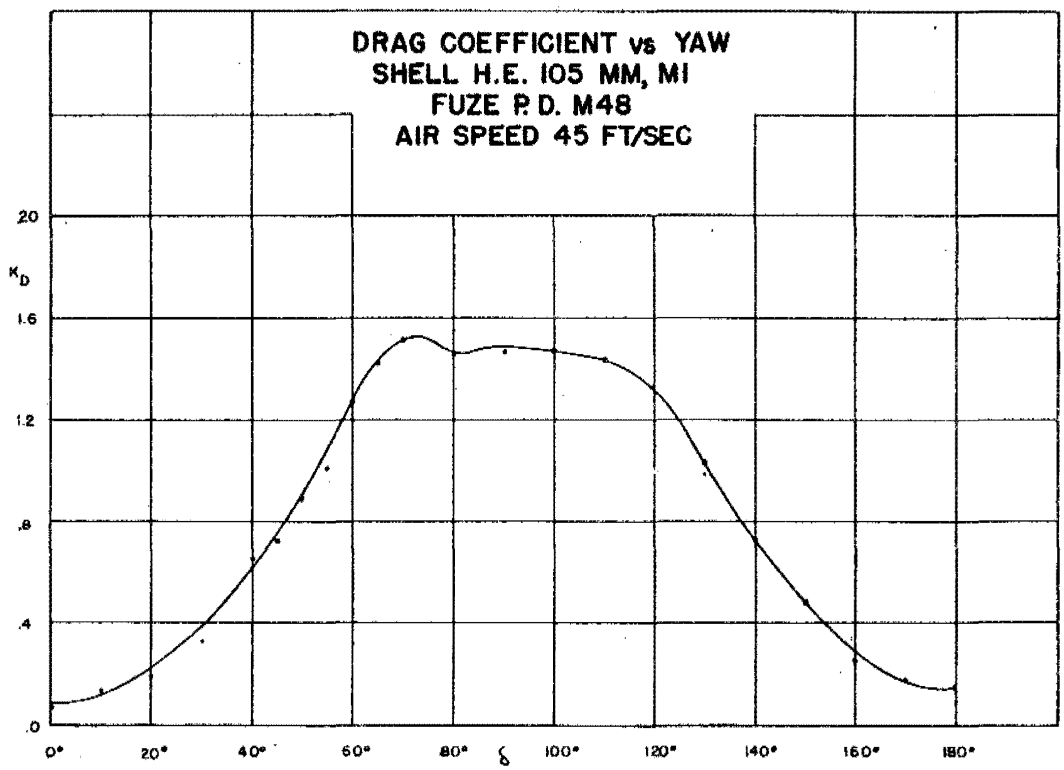
*From base of shell without projections.

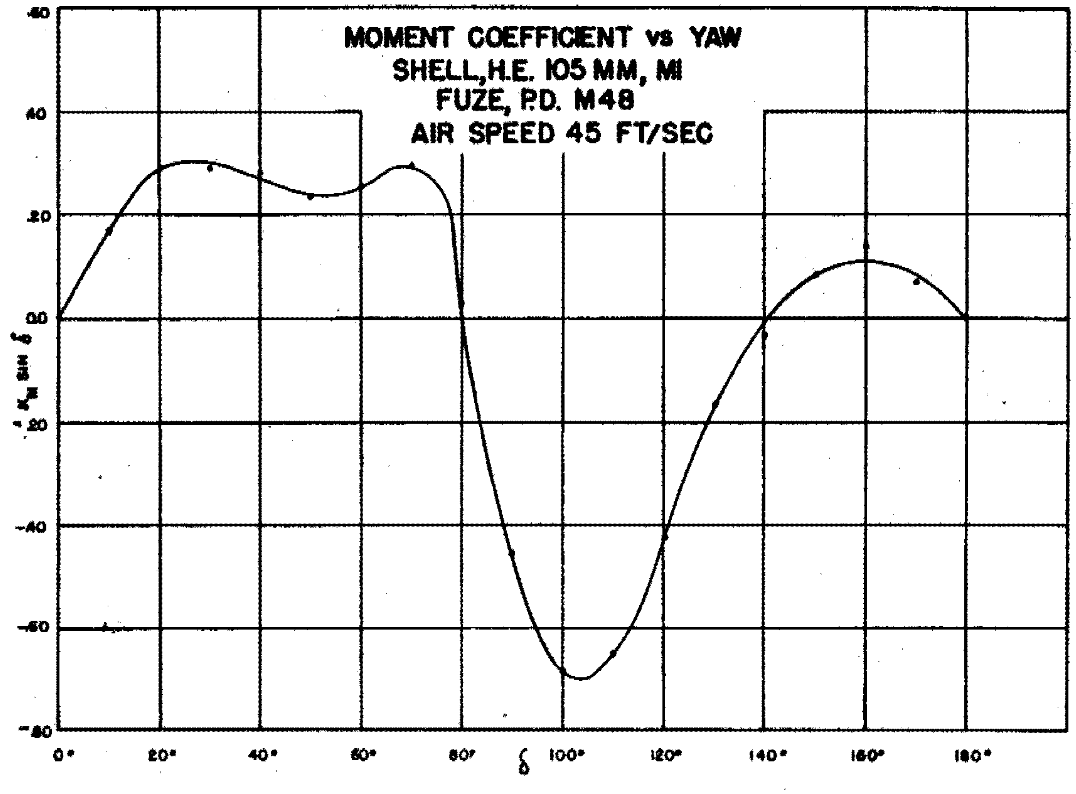
c. Drag

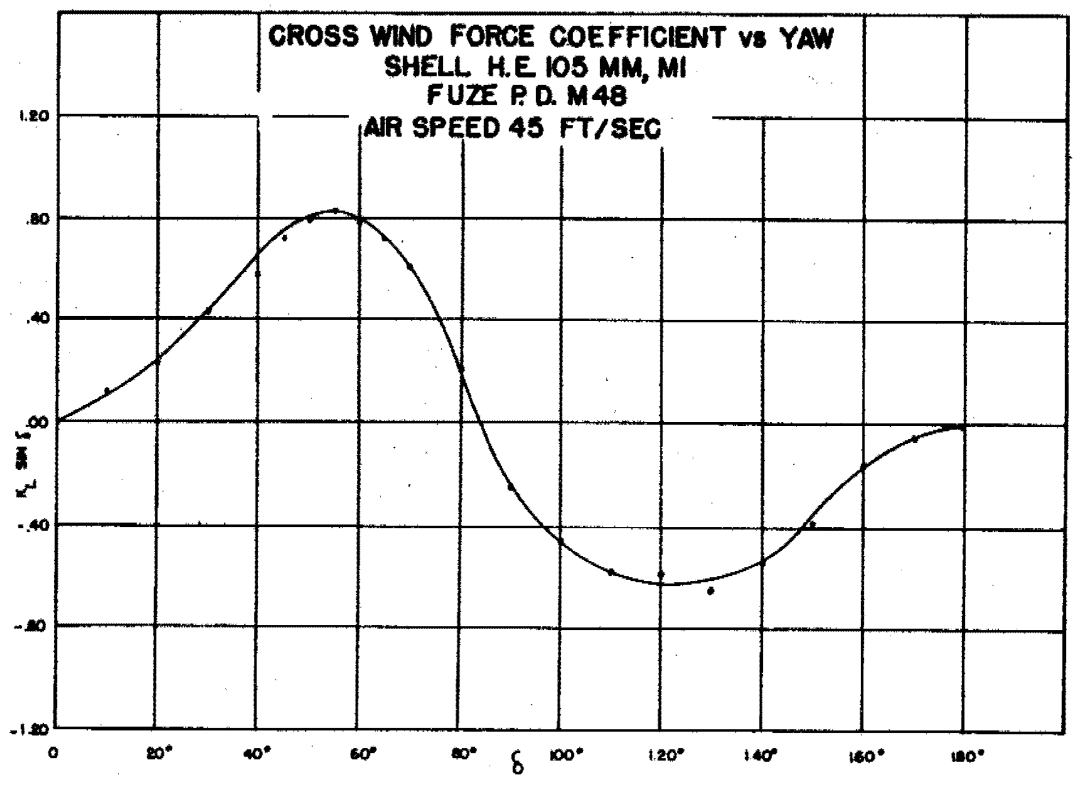
Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
H.V.A.P. T29E4	Tracer	MR 411	Time	8	1.12	3358	1.07
H.E. M1	M48	BRL 166 Nov 41	Resist.	5	1.02	1550	.177
H.E. M1	M78	K-I-9 Mar 44	Resist.	5	0.93	1519	.161
H.E. M1	M48		Resist.		See graph		
H.E. M1	M48	BRL 338	Air Stream*		See graph		
H.E. M1	Circular Plug	BRL 284	Resist.	5	0.79	650	.048
					1.05	1020	.078
					1.37	1550	.237
H.E. M1	Hex. Plug	BRL 284	Resist.	5	1.29	650	.078
					0.71	1020	.053
					1.23	1550	.213
H.E. T30E1	M51A4	MR 411	Time	8	1.04	2930	.107
					0.98	2266	.126
H.E.A.T. M67	M62	Memo Nov 42	Resist.	2	1.06	1018	.078
H.E.A.T. M67	M62	Memo Oct 44	Resist.	2	1.07	1241	.172
Practice M67	T121	Memo Oct 44	Resist.	2	1.06	1239	.169
H.E.A.T. M67	T93	APG 471.822/1330	Resist.	2	1.04	1250	.167

*The drag, torque and cross wind force of a wooden model of the H.E. Shell M1 were measured by the Bureau of Standards in an air stream with a "Standard air speed" of 45 ft/sec and a "Standard air density" of 0.0765 lb/ft^3. The drag coefficient, moment coefficient (relative to the center of gravity of the actual projectile) and cross wind force coefficient shown on the following graphs were deduced from the air stream measurements and smoothed. The yaw-drag coefficient, approximately valid for yaws from 0° to 65°, is 0.00414 per deg.^{2}


DRAG COEFFICIENT
vs MACH NUMBER
105 MM SHELL, H.E. M1
FUZE, P.D., M48
4.675
.74
.19
1.40
1.44
.905
6.17 R
9°
K_D
.20
.15
.10
.05
0
0
.25
.50
.75
1.0
M
1.25
1.5
1.75
2.0
2.25
2.5


DRAG COEFFICIENT vs YAW
SHELL H.E. 105 MM, M1
FUZE P.D. M48
AIR SPEED 45 FT/SEC
2.0
K_D
1.6
1.2
.8
.4
.0
0°
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°


MOMENT COEFFICIENT vs YAW
SHELL, H.E. 105 MM, MI
FUZE, P.D. M48
AIR SPEED 45 FT/SEC


CROSS WIND FORCE COEFFICIENT vs YAW
SHELL H.E. 105 MM, MI
FUZE P.D. M48
AIR SPEED 45 FT/SEC

15. 105mm and 4.2-inch Projectiles (Con.)

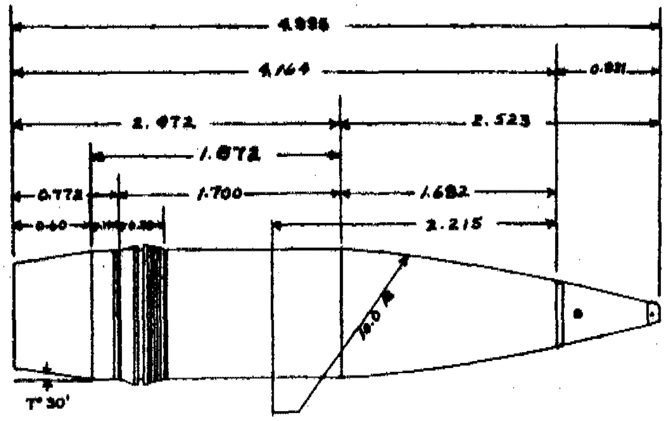
d. Stability

Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	n cal	s	K_M
A.P.C. T13E2	M66A1		6	2800	30	1.92	1.57
H.V.A.P. T29E4	Tracer	MR 411	5	3700	30	2.01	0.86
H.E. M1	M54	Memo	1	2675	30	1.35	1.28
H.E. M1	M59 Dummy	BRLM 265	7	1550	20	2.69	1.41*
H.E.A.T. M67	M62		1	778	27	1.13	2.07
H.E.A.T. M67	M62		3	1285	27	1.41	1.66
H.E.A.T. M67E1	M62A1		3	1285	27	1.18	2.00
H.E.A.T. E81 (4.2" Mortar)	M62A1 Mod.	APG 471.381/33	5	670	20	1.42	1.21
Chem. (WP) M60	M48		3	1230	27	1.16	1.78
Smoke (BE) M84	M54		3	1270	27	1.58	1.52
Illuminating (BE) M314	M54		3	1226	27	1.98	1.37

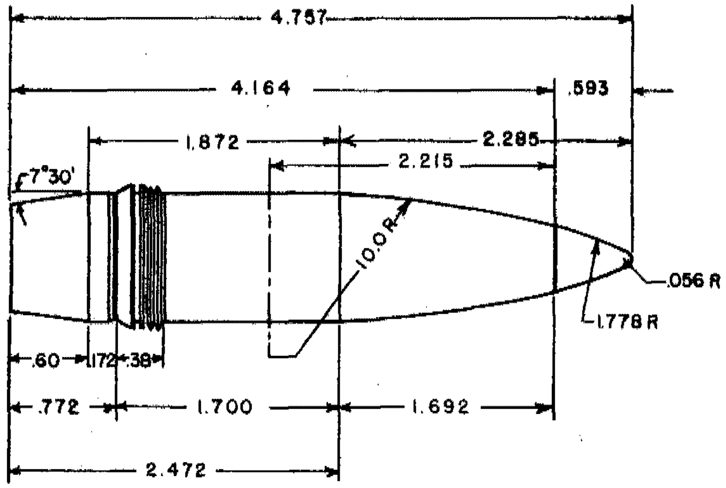
*See par. 15c and graph.

e. Pitch of Rifling

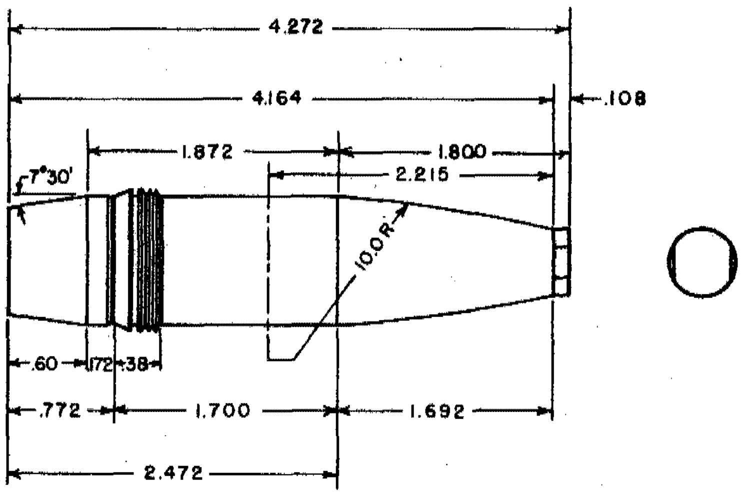
Cannon	Caliber in.	n cal
Gun (A.A.) 105mm, M3	4.134	30
Gun (A.A.) 105mm, T4 (L.H. twist)	4.134	30
Gun, 105mm, T5E1 and T8	4.134	30
How., 105mm, M2A1, M3 and M4	4.134	20
How., 105mm, M2A1E3	4.134	27
Mortar, Chem., 4.2", E34R1	4.200	20



SHELL, H.E., 4.5", M65 WITH P.D. FUZE M51A1



SHELL, H.E., 4.5-INCH, M65; FUZE, C.P., M78



SHELL, H.E., 4.5-INCH, M65; PLUG, CLOSING, 75-14-309E

ALL DIMENSIONS IN CALIBERS

16. 4.5-inch Projectiles

a. Drawings

Shell, High Explosive, M65	75-2-297
Fuze, Point Detonating, M48	73-2-140
Fuze, Point Detonating, M51	73-2-145
Fuze, Concrete Piercing, M78 (T105 Type 6)	73-2-214
Plug, Closing	75-14-309E
Plug, Circular	
Fuze, Experimental, National Defense Research Committee (same contour as M48 and M51 Fuzes)	

b. Physical Characteristics

Projectile	Fuze	Weight Lb Std	Weight Lb Meas	No. of Rounds	g cal	A lb.ft.^{2}	B lb.ft.^{2}
H.E. M65	M48	55.00	54.99	4	1.837	1.004*	10.79*
H.E. M65	M51	55.00					
H.E. M65	M78	55.72	55.75	5	1.853	1.187*	11.45*

*These values appear to be erroneous when compared with the moments of inertia of other H.E. Shells (See BRL MR 285).

c. Drag

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
H.E. M65	M48	BRL 284 Aug 42	Resist.	2	1.05	1806	.141
					0.99	2252	.114
H.E. M65	M78	Memo Mar 44	Resist.	2	1.18	2245	.136
H.E. M65	Plug, Closing	Memo June 42	Resist.	2	1.67	1799	.225
					1.82	1998	.227
					1.96	2268	.224
					1.92	2269	.220
H.E. M65	Circular Plug	BRL 284	Resist.	5	1.38	1842	.233

d. Stability

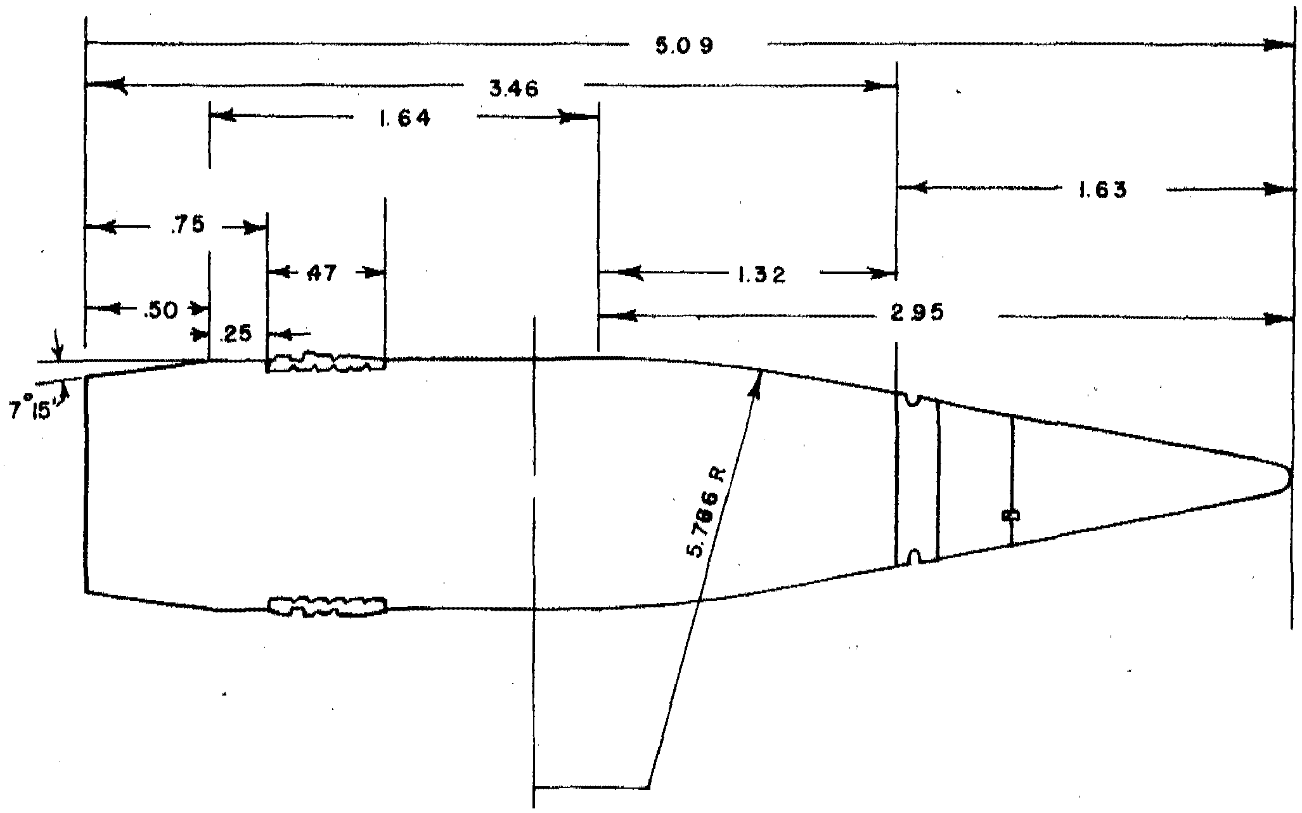
Pitch of Rifling: 25 calibers

Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	s	K_M
H.E. M65	M51	BRLM 285	8	2275	2.00	1.33
H.E. M65	M78	BRLM 285	5	2270	1.75	1.99

16. 4.5-inch Projectiles (Con.)

e. Spin

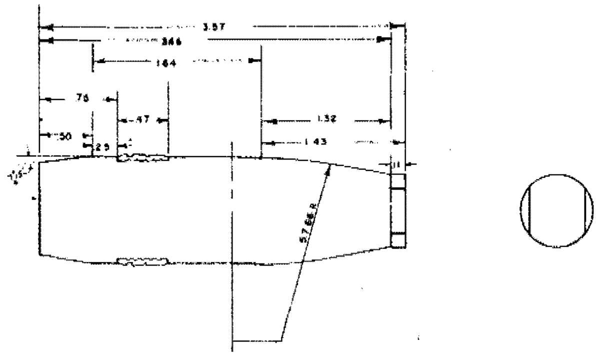
Shell	H.E. M65
Fuze	N.D.R.C.
S'/d^2	13.1
Report	BRL 408
No. of Rds.	3
Gun	M1 (n = 25)
Muzzle Velocity	2275 and 1820
Reynold's No.	3.59×10^6
K_A	0.00535
C'_{DF}	0.00163



SHELL, H.E., 120MM, M73; FUZE, M.T., M61

ALL DIMENSIONS IN CALIBERS

17. 120mm Projectiles



SHELL, H.E., 120MM, M73; PLUG, CLOSING 75-14-309E **ALL DIMENSIONS IN CALIBERS**

a. Drawing

Shell, High Explosive, M73 (T5)	75-18-40
Fuze, Mechanical Time, M61 (T31E2)	73-7-71
Plug, Closing	75-14-309E

Fuze, Experimental, T75E6 (the plastic cap of this fuze has the same contour as the M61 Fuze.)

b. Physical Characteristics

Projectile	H.E. M73
Fuze	M.T. M61
Weight: Standard	50.00 lb.
Measured	49.76 lb.
No. of Rds.	10
g (7.90")	1.681 cal
A	1.072 lb.ft.^{2}
B	8.550 lb.ft.^{2}

c. Drag

Projectile	H.E. M73
Fuze	Plug, Closing
Report	BRL 284 Aug. 42
Observation	Resistance
Projectile Type	1
Form Factor	1.18
Velocity	3000 ft/sec
K_D	.244

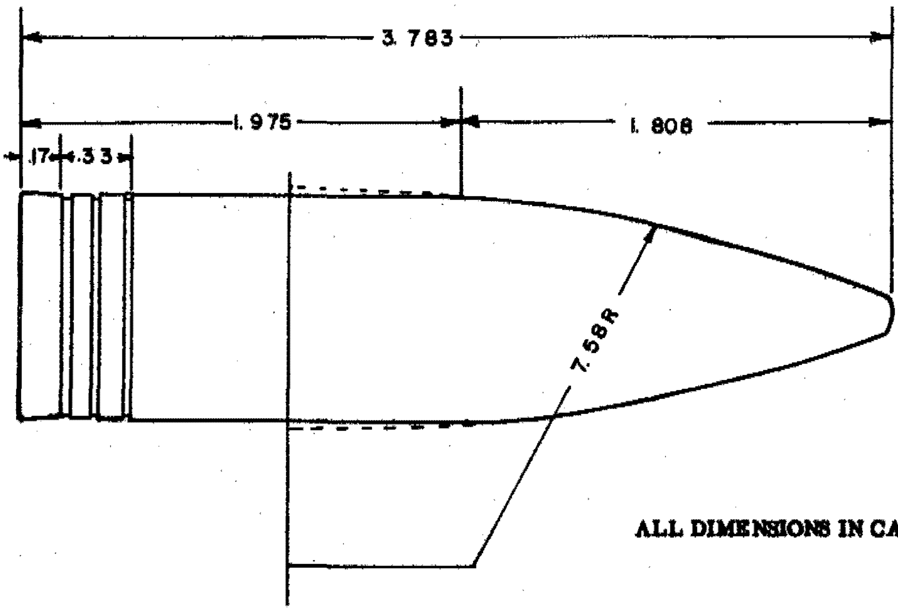
d. Stability

Shell	H.E. M73
Fuze	M.T. M61
Report	BRL 237 (Rev. July 41)
No. of Rds.	10
Velocity	3040 ft/sec
Mach No.	2.643
Cannon	6" Gun M1900 with 4.7" liner T2
Caliber	4.700 in.
n	25 cal
s	2.84
K_M	1.08

e. Spin

Shell	H.E. M73
Fuze	T75E6
S'/d^2	12.2
Report	BRL 569
No. of Rds.	10
Gun	120MM M1
Caliber	4.700 in
n	30 cal
Muzzle Velocity	3010 ft/sec
Reynold's No.	$(1.12 \text{ to } 3.79) \times 10^6$
K_A	0.00482
C'_{DF}	0.00158

18. 6-inch Projectiles



PROJECTILE, COMMON, 6", MARK 20

a. Drawing

Projectile, Common, Mark 20 Naval Bureau of Ord. 57012

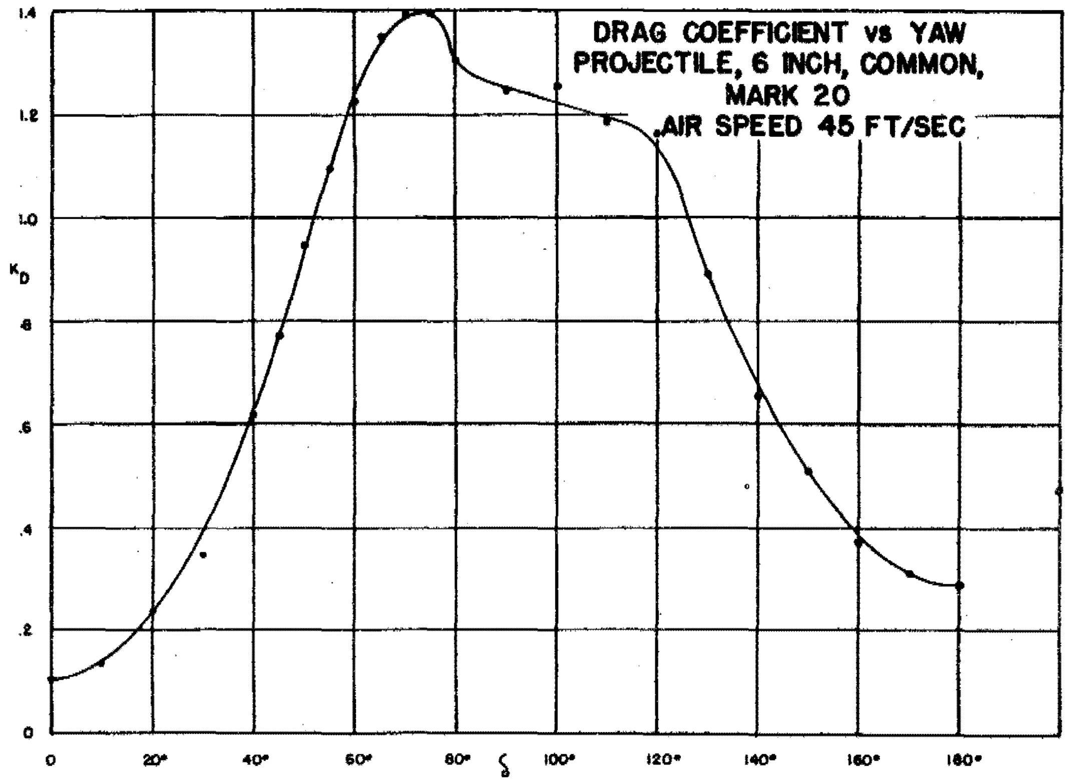
b. Physical Characteristics

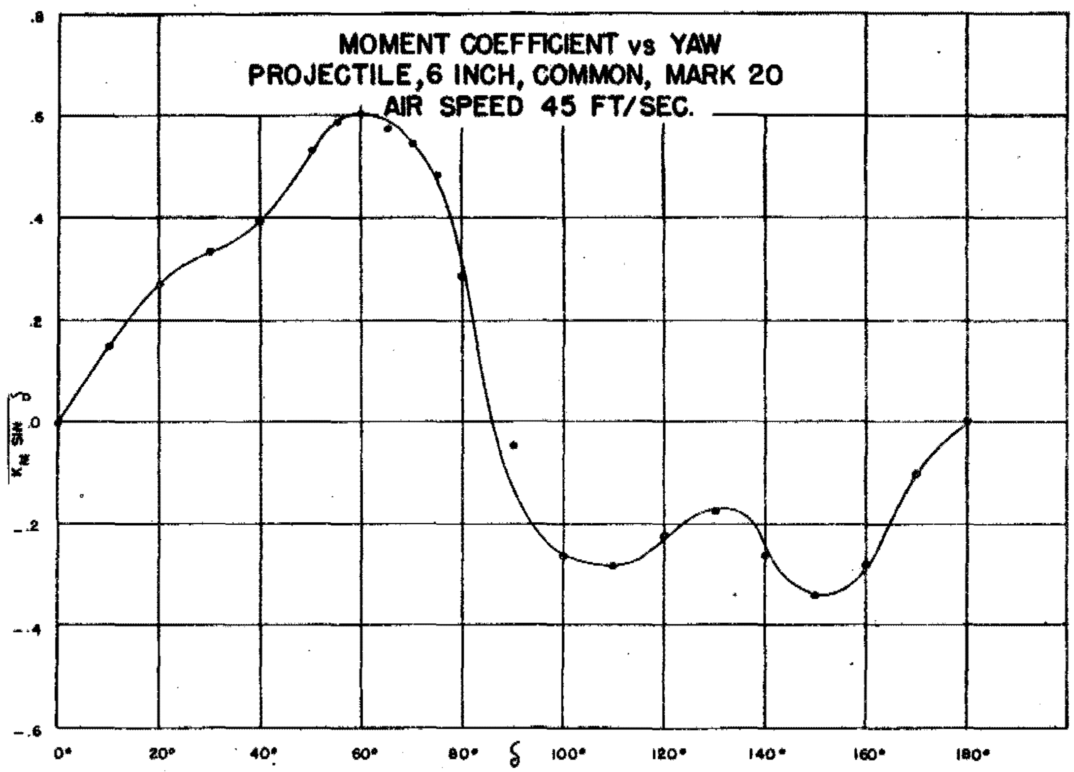
Projectile	Common, Mark 20
Weight*	103.3 lb
g*	1.533 cal
A*	3.354 lb.ft^2
B*	24.65 lb.ft^2

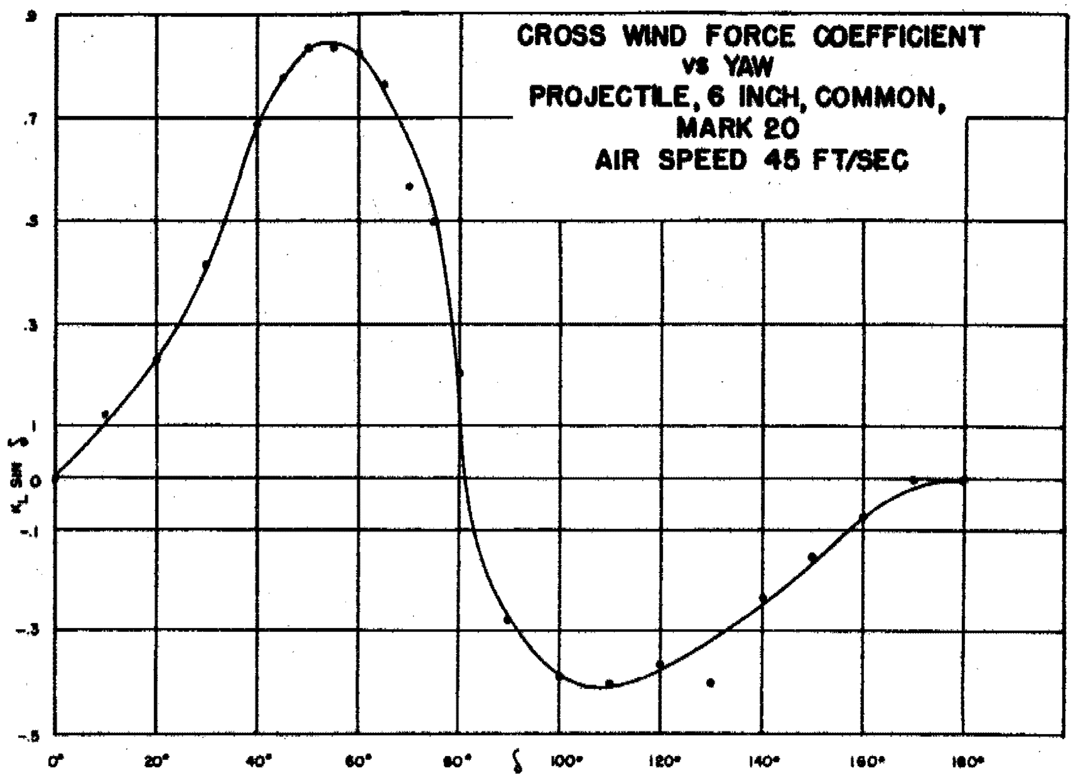
*Computed from dimensions on drawing.

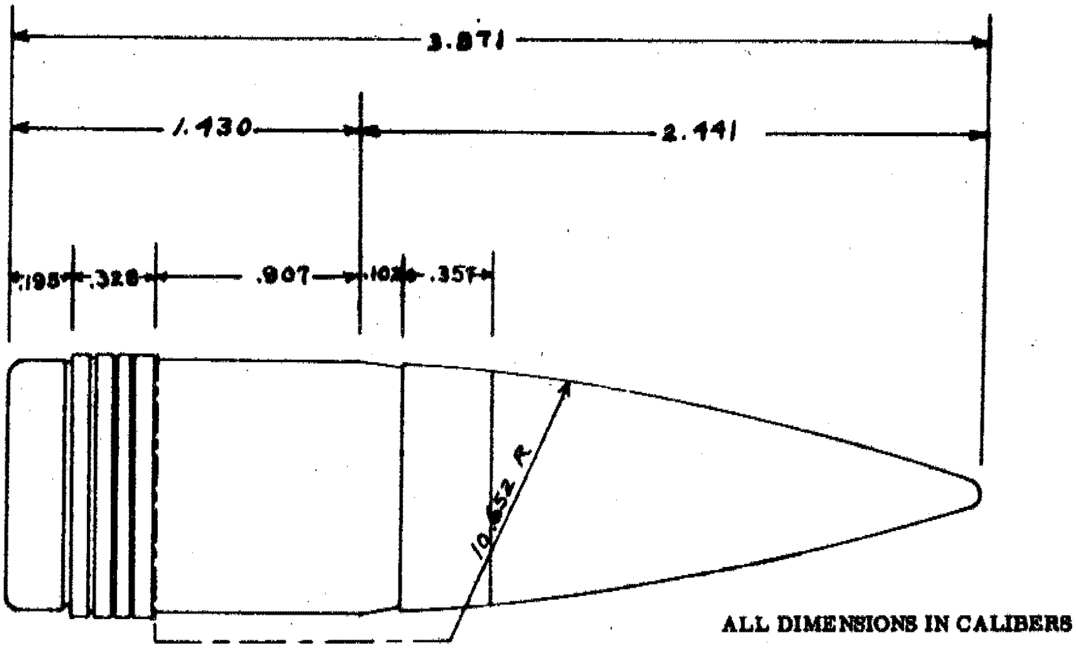
c. Drag, Moment and Cross Wind Force:

The drag, torque and cross wind force of a wooden model of the Navy 6" Common Projectile were measured by the Bureau of Standards in an air stream with a "standard air speed" of 45 ft/sec and a "standard air density" of 0.0765 lb/ft^3. The results are given in BRL Report 261, which also includes data taken from the Naval Proving Ground Report S-72-4(49) on underwater trajectories. The drag coefficient, moment coefficient (relative to the center of gravity of the actual projectile) and cross wind force coefficient shown on the following graphs were deduced from the air stream measurements and smoothed. The yaw-drag coefficient, valid for yaws from 0 to 55°, is 0.00325 per deg^2.

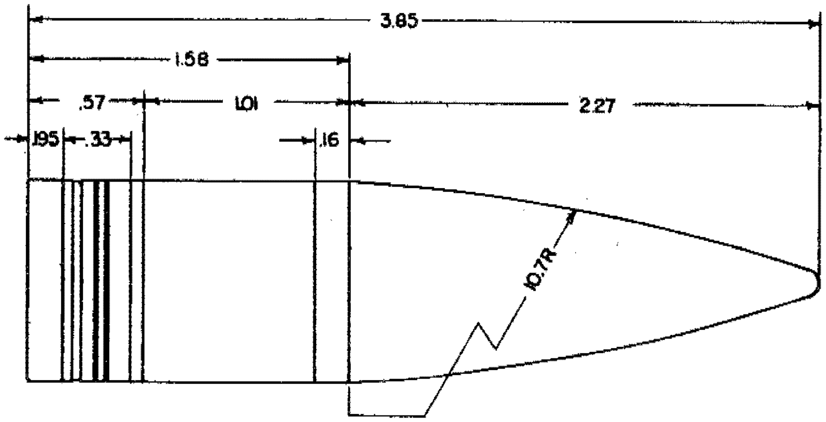

DRAG COEFFICIENT vs YAW
PROJECTILE, 6 INCH, COMMON, MARK 20
AIR SPEED 45 FT/SEC
K_D
0
.2
.4
.6
.8
1.0
1.2
1.4
0
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°


MOMENT COEFFICIENT vs YAW
PROJECTILE, 6 INCH, COMMON, MARK 20
AIR SPEED 45 FT/SEC.
.8
.6
.4
.2
.0
-.2
-.4
-.6
0°
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°

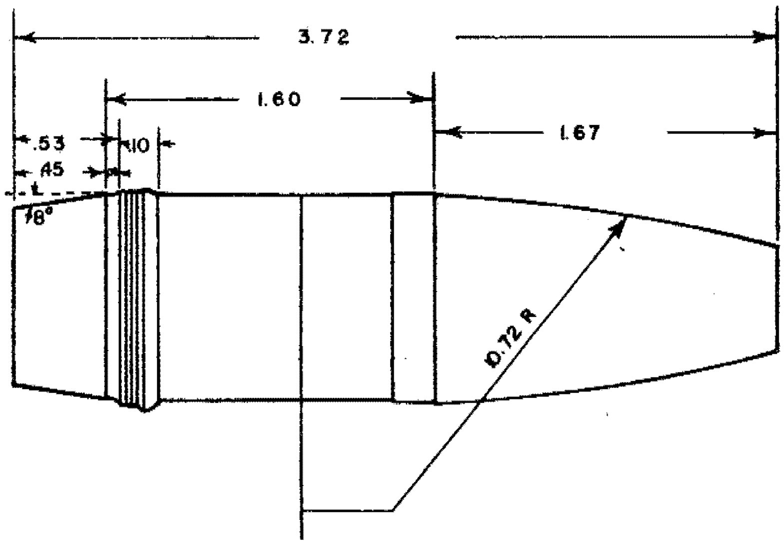




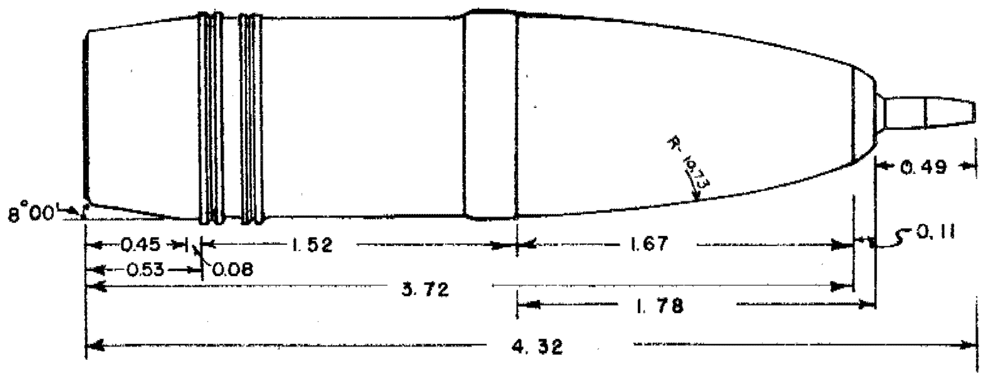
PROJECTILE, A.P., 155MM, M112



SHOT, H.V.A.P., 155MM, T35

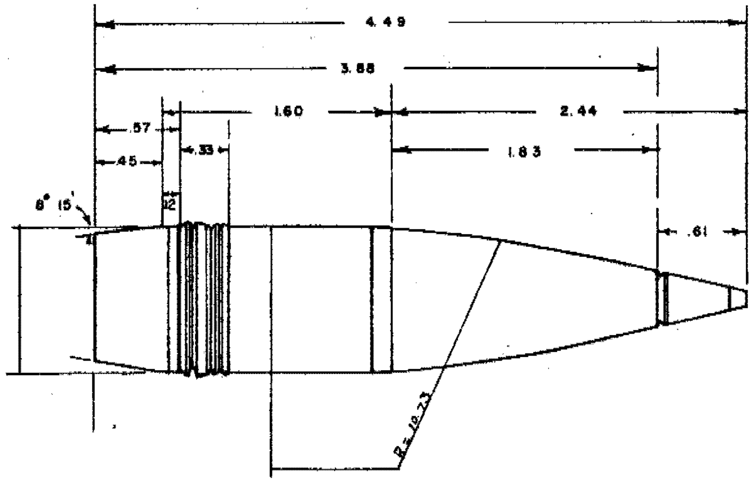


SHELL, H.E., 155MM, MARK I; WOODEN PLUG

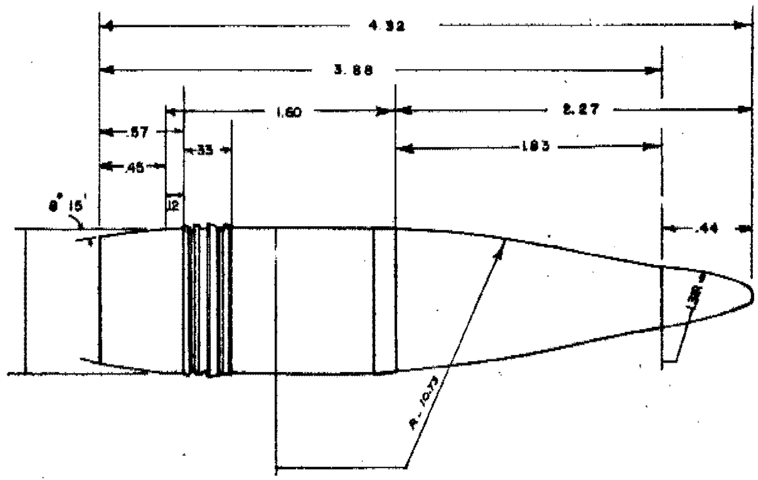


SHELL, H.E., 155MM, MARK 3; FUZE, P.D., M46

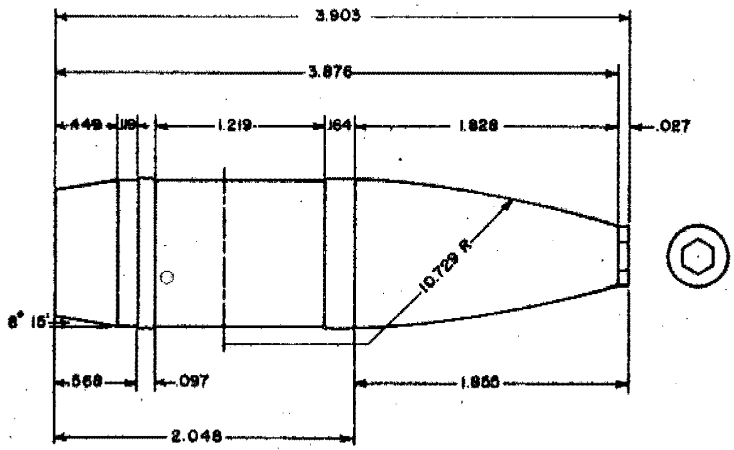
ALL DIMENSIONS IN CALIBERS



SHELL, H.E., 155MM, M101; FUZE, P.D., M51A1

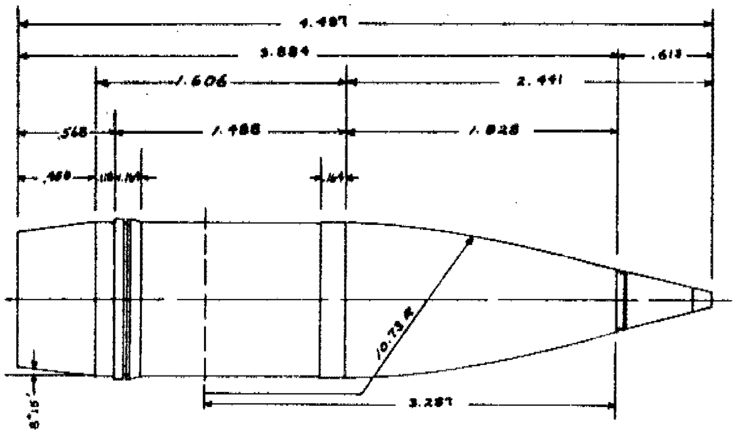


SHELL, H.E., 155MM, M101; FUZE, C.P., M78



SHELL, H.E., 155MM, M102; HEXAGONAL PLUG

ALL DIMENSIONS IN CALIBERS

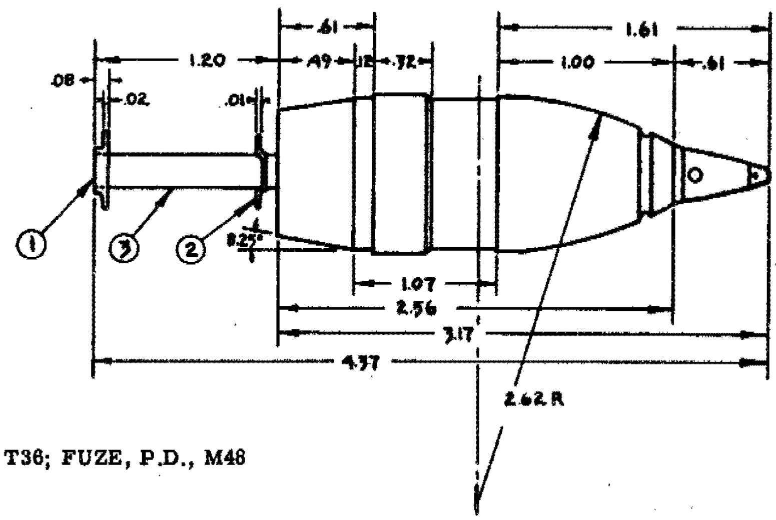


SHELL, H. E., 155MM, M107; FUZE, P.D., M51

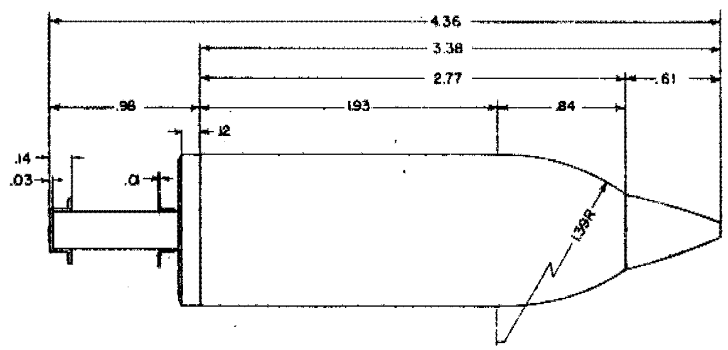
1 RETAINING CAP

2 RETAINING CLIP

3 CARTRIDGE CONT[illegible]ER

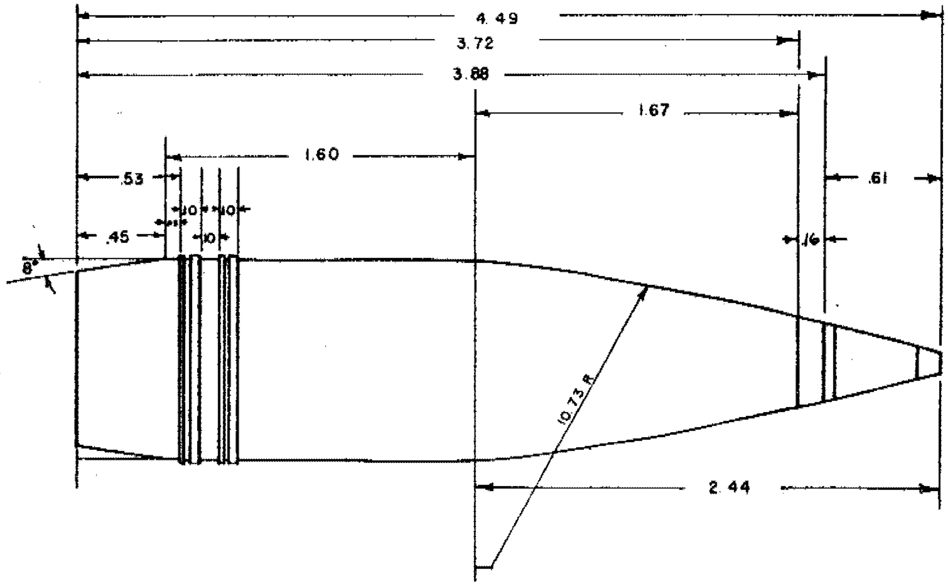


SHELL, H.E., 155MM, T36; FUZE, P.D., M48

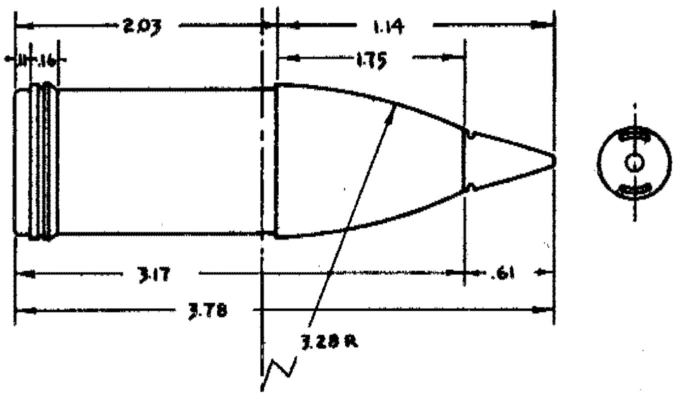


SHELL, H.E., 155MM, T24E1; FUZE, P.D., M48

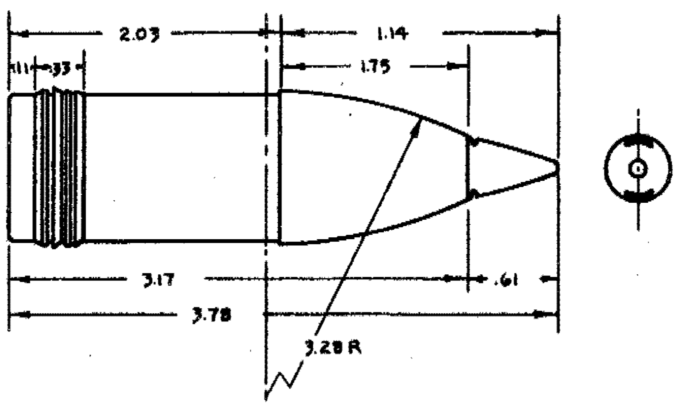
ALL DIMENSIONS IN CALIBERS



SHELL, CHEM., 155MM, MARK 7A1; FUZE, P.D., M57



SHELL, ILLUMINATING, 155MM, M118; FUZE, DUMMY, M59



SHELL, ILLUMINATING, 155MM, T22; FUZE, M.T., T17

ALL DIMENSIONS IN CALIBERS

19. 155mm Projectiles

a. Drawings

Projectile, Armor-piercing, M112, M112B1 and M112B2	75-4-101
Shot, Hypervelocity Armor-piercing, T35	TAM 1417 & 1412
Shell, High Explosive, Mark 1	75-4-25
Shell, High Explosive, Mark 3	75-4-36
Shell, High Explosive, M101 (T2)	75-4-80
Shell, High Explosive, M102	75-4-82
Shell, High Explosive, M107	75-4-99
Shell, High Explosive, T24E1 (with the 3-1/2 inch increment cartridge container, 457G)	TAM 456 & 457
Shell, High Explosive, T36	TAM 1433, 1434 & 1826
Shell, Chemical, Mark 7A1	75-4-86
Shell, Illuminating, M118 (T21)	TAM 72
Shell, Illuminating, T22	TAM 72
Adapter-Booster, Mark IIIA1 (Adapts H.E. Shell Mark 3 to P.D. Fuze M46)	73-1-55
Fuze, Point Detonating, M46	73-2-126
Fuze, Point Detonating, M48	73-2-140
Fuze, Point Detonating, M51, M51A1 and M51A2	73-2-145
Fuze, Point Detonating, M57 (T18E2)	73-2-138
Fuze, Experimental, National Defense Research Committee (same contour as M48, M51, M57 and M59 Fuzes)	
Fuze, Concrete Piercing, M78 (T105 Type 6)	73-2-214
Fuze, Dummy, M59	72-5-5
Fuze, Mechanical Time, T17 (same contour as M.T. Fuzes M43 & M67, P.D. Fuzes M48, M51 & M57, etc.)	
Fuze, Base Detonating, M60	73-2-74

19. 155mm Projectiles (Con.)

b. Physical Characteristics

Projectile	Fuze	Weight Lb. Std	Weight Lb. Meas	No. of Rounds	g cal	A lb.ft.^{2}	B lb.ft.^{2}
A.P. M112B2	M60	100	98.54	19			
H.V.A.P. T35			56.50	1			
H.E. Mk 3	M46	94.7	93.56	10	1.536	3.349	29.73
H.E. M101	M48	95.0	93.75	20	1.538	3.434	28.88
H.E. M101	M51A1	95.0	95.04	21			
H.E. M101	M78	95.72	95.02	5	1.552	3.35	30.90
H.E. M107	M51	95.0					
H.E. T24E1	M48		57.70				
			calculated from design				
H.E. T36	M48		56.00		1.092	1.938	10.72
Same w/o clip	M48		56.00		1.092	1.938	10.72
W/o retaining cap	M48		53.53		1.103	1.936	10.38
{W/o retaining cap or clip}	M48		53.53		1.103	1.936	10.38
{W/o cartridge container, retaining cap or clip}	M48		51.84		1.155	1.932	9.01
			Meas.				
Chem. Mk 7A1	M57	94.83 (HS)	96.68 (Simulated HS)	20			
Illum. M118	M59	103.06	101.44	1	1.413	3.78	23.80
Illum. T22	T17		102.18	1	1.408	3.83	25.41

c. Drag

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
A.P. M112B1	M60	Memo Jan 44	Resist.	6	0.88	1453	.152
A.P. M112	M60	Memo Jan 44	Resist.	6	0.88	1815	.139
A.P. M112B2	M60	K-I-9 Mar 44	Resist.	6	0.91	2037	.135
A.P. M112B2	M60	Memo Feb 44	Resist.	6	0.91	2341	.122
H.V.A.P. T35		Memo May 45	Time	8	1.03	3630	.092
H.E. Mk 1	Wood Plug	BRL 166 Nov 41	Resist.	5	0.98	1082	.101
					1.21	1357	.207
					1.45	1476	.250
H.E. M101	M51A1	K-I-9 Mar 44	Resist.	5	0.80	1951	.132
		Memo Feb 44			0.80	2080	.127
		BRLM 287			0.84	2396	.122
					0.83	2779	.112
H.E. M101	M78	BRLM 287	Resist.	5	0.88	2396	.128

19. 155mm Projectiles (Con.)

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
H.E. M101	M51A1	BRL 16 & 338	Air Stream*			See graphs	
H.E. M102	Hex. Plug	BRL 166 Nov 41	Resist.	5	1.28	1995	.208
H.E. M107	M51	Memo Jan 44	Resist.	2	0.93	872	.061
					1.04	1013	.076
					1.00	1208	.161
					1.11	1511	.167
					1.23	1844	.162
H.E. T36	M48	N.B.S. VI-4/64 Jan 45	Wind tunnel	1	0.771	100	.0756
Same w/o clip	M48			1	0.806	100	.0791
W/o retaining cap	M48	APG 471.151/555 and 557	full scale,	1	0.640	100	.0628
W/o retaining cap or clip	M48		wooden plug	1	0.644	100	.0632
W/o cartridge container, retaining cap, or clip	M48			1	0.704	100	.0691
		These values are for 0° yaw; see K_D curves					
						Mach No.	
H.E. T36 w/o clip	M48	BRLM 361	Wind tunnel 2-in models	1	0.40	0.6	.032
					0.30	0.8	.030
					0.33	0.9	.044
W/o retaining cap or clip	M48			1	0.31	0.6	.025
					0.29	0.8	.029
					0.31	0.9	.042
W/o cartridge container, retaining cap or clip	M48			1	0.44	0.6	.035
					0.35	0.8	.035
					0.37	0.9	.050
				These values are for 0° yaw.			
						Velocity	
Illum. M118	M59	Memo Apr 44	Resist.	6	0.935	640	.078
					1.02	969	.089
Illum. T22	T17	Memo Apr 44	Resist.	6	1.11	1439	.192
					1.13	1988	.180

*Measurements of underground trajectories of H.E. Shell M101 are given in BRL Report 16. The drag, torque and cross wind force of a wooden model were measured by the Bureau of Standards in an air stream with a "standard air speed" of 45 ft/sec and a "standard air density" of 0.0765 lb/ft^3. The drag coefficient, moment coefficient (relative to the center of gravity of the actual projectile) and cross wind force coefficient shown on the following graphs are smoothed results deduced from the air stream measurements of the model placed in two opposite orientations. The yaw-drag coefficient, approximately valid for yaws from 0 to 55°, is 0.00508 per deg^2.

19. 155mm Projectiles (Con.)

d. Stability.

Pitch of Rifling 29.89 calibers (Angle 6°)

Projectile	Fuze	Report	No. of Rounds	Velocity ft/sec.	Mach No.	s	K_M
H.E. Mk 3	M46	BRL 162	5	1929	1.689	1.41	1.22
H.E. M101	M48	BRL 162	7	1934	1.685	1.28	1.36
			7	2415	2.132	1.41	1.21
H.E. M101	M78	BRLM 287	6	2410		1.48	1.06
H.E. M101	M51A1	BRL 16 & 338	See par. 19c and graph				
H.E. T24E1	M48	Memo Dec 44		972		1.31	0.72
Chem. Mk 7A1 (Simulated HS)	M57	BRL 217	6	1967	1.801	1.32	
			5	2443	2.243	1.44	
			Pitch of rifling 30 calibers				
H.E. T36	M48	N.B.S. VI-4/64	Full scale models in wind tunnel	100		1.23	1.22
Same w/o clip	M48	Jan 45		100		1.33	1.13
W/o retaining cap	M48	APG 471.151/555		100		1.32	1.18
W/o retaining cap or clip	M48			100		1.32	1.17
W/o cartridge container, retaining cap or clip	M48			100		2.47	0.72
			These values are for 0° yaws; see K_M curves.				
H.E. T36 w/o clip	M48	BRLM 361	2-in models in wind tunnel		0.6	1.37	1.1
					0.8	1.37	1.1
					0.9	1.16	1.3
W/o retaining cap or clip	M48				0.6	1.48	1.05
					0.8	1.29	1.2
					0.9	1.29	1.2
W/o cartridge container, retaining cap or clip	M48				0.6	1.78	1.0
					0.8	1.98	0.9
					0.9	1.48	1.2

These are average values for yaws up to 10°.

19. 155mm Projectiles (Con.)

e. Cross Wind Force

Projectile	Fuze	Report	Model Dia.	Mach No.	K_L
H.E. T36 w/o clip	M48	BRLM 361	2-in.	0.6	.59
				0.8	.58
				0.9	.53
W/o retaining cap or clip	M48			0.6	.59
				0.8	.59
				0.9	.53
W/o cartridge container, retaining cap or clip	M48			0.6	.66
				0.8	.66
				0.9	.60

These are average values for yaws up to 10°

See graphs of cross wind force ceofficient, normal force coefficient, and distance from center of pressure to base of shell body, determined from measurements by National Bureau of Standards on full scale models.

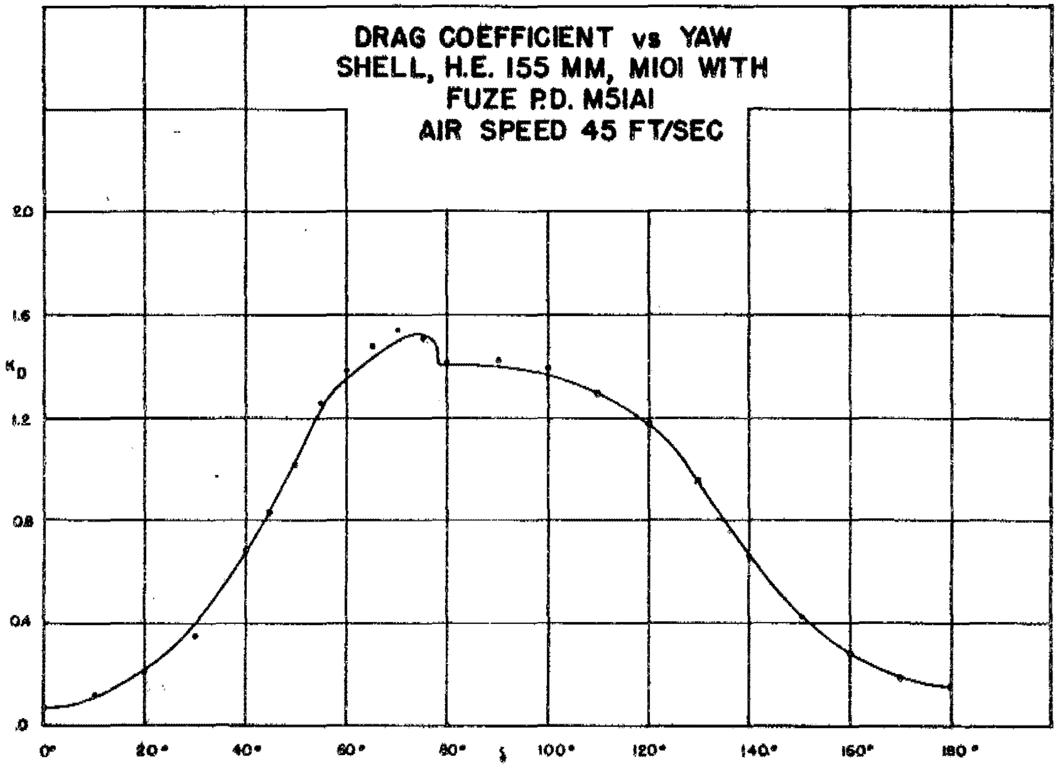
H.E. M101	M51A1	BRL 338	155MM	See par. 19c and graph

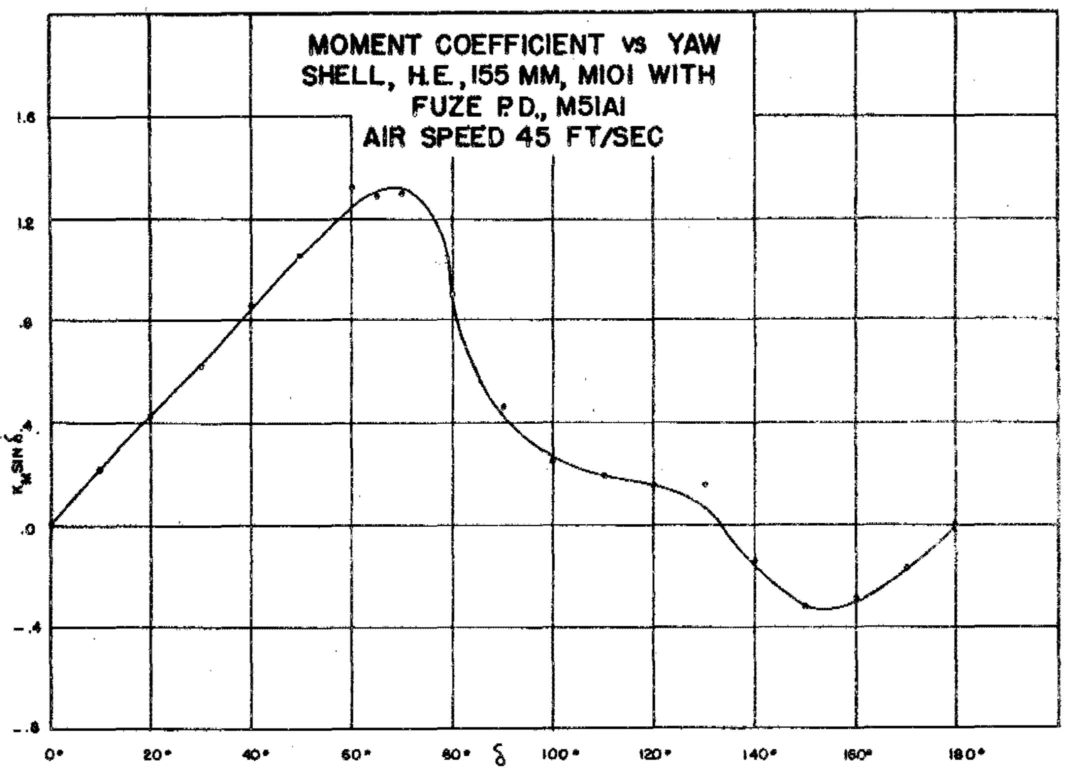
f. Spin

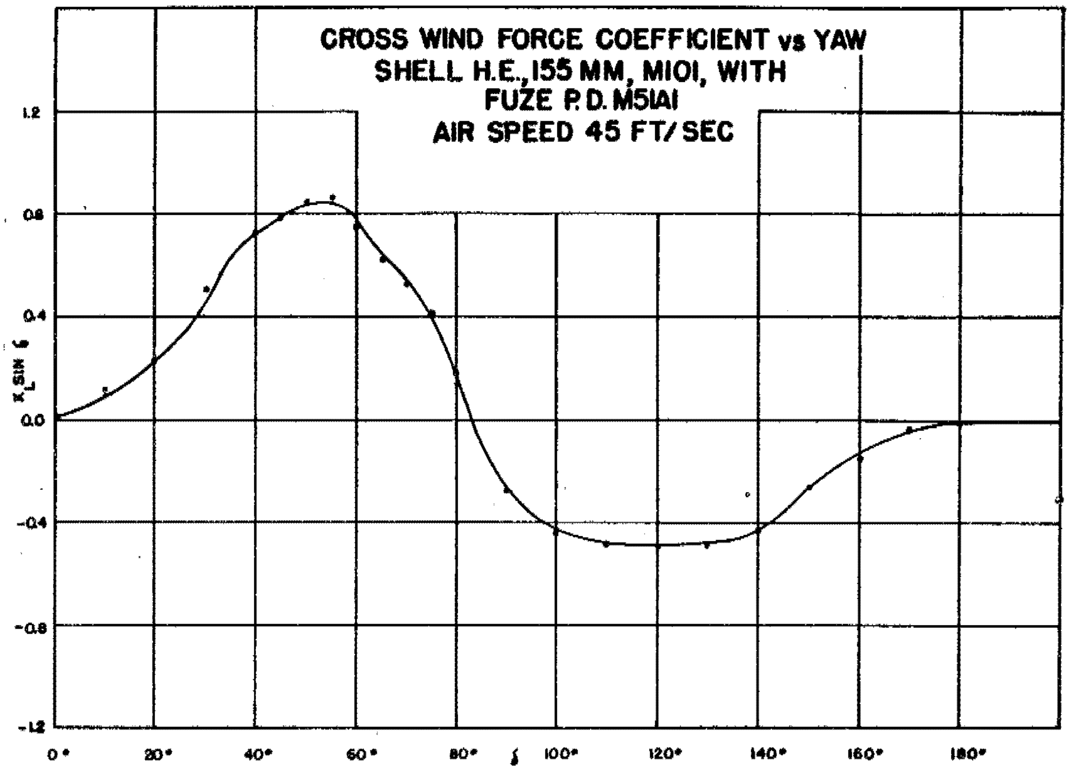
Shell	H.E. M101
Fuze	N.D.R.C.
S'/d^2	10.8
Report	BRL 408
No. of Rds.	2
Gun	M1A1 (n = 25)
Muzzle Velocity	2100 and 2800 ft/sec
Reynold's No.	5.38×10^6
K_A	0.00395
C'_{DF}	0.00147

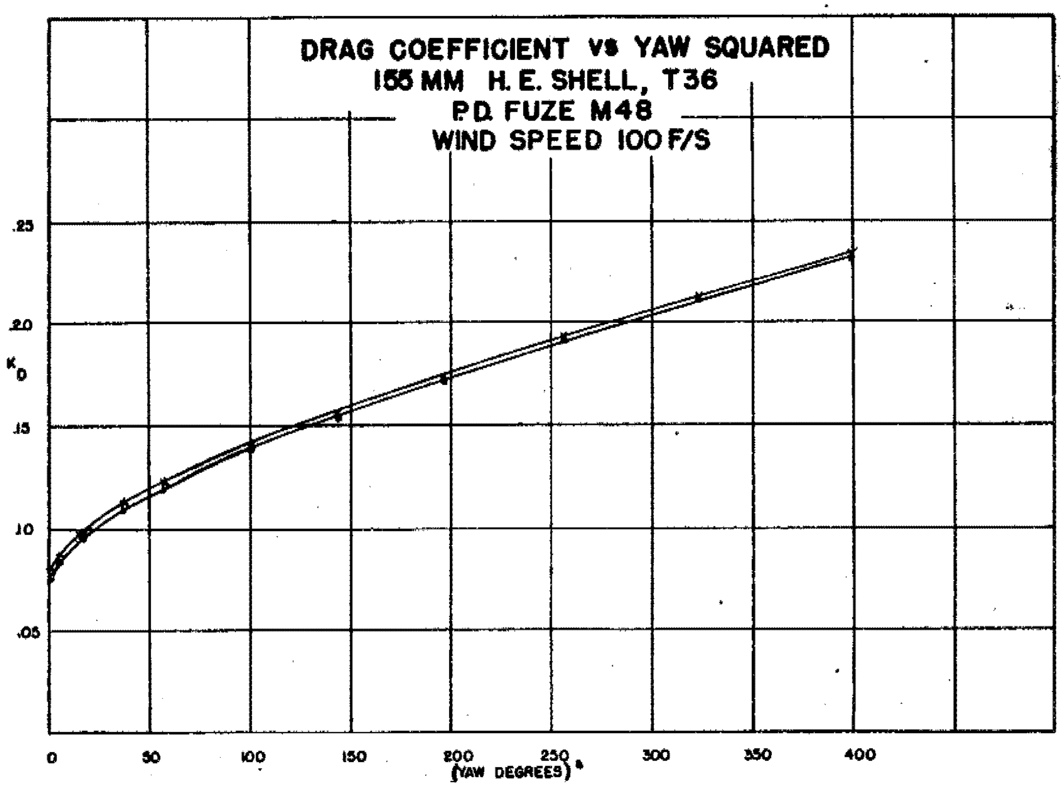
g. Pitch of Rifling of 155mm Guns (6.102")

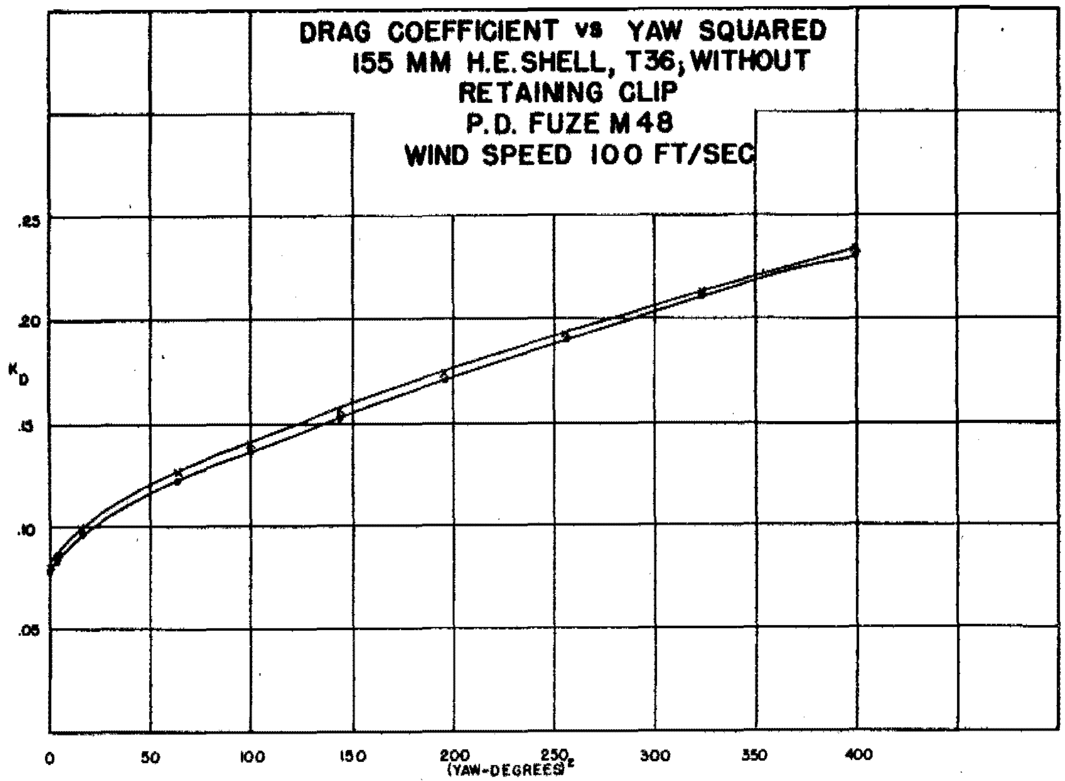
Gun	n-cal
Guns, M1917, M1917A1 and M1918M1	29.89
Guns, M1, M1A1, M2 and M3	25
Howitzers M1917, M1917A1, M1917A2 and M1918	25.586
Howitzer M1	25
Mortar T10	30

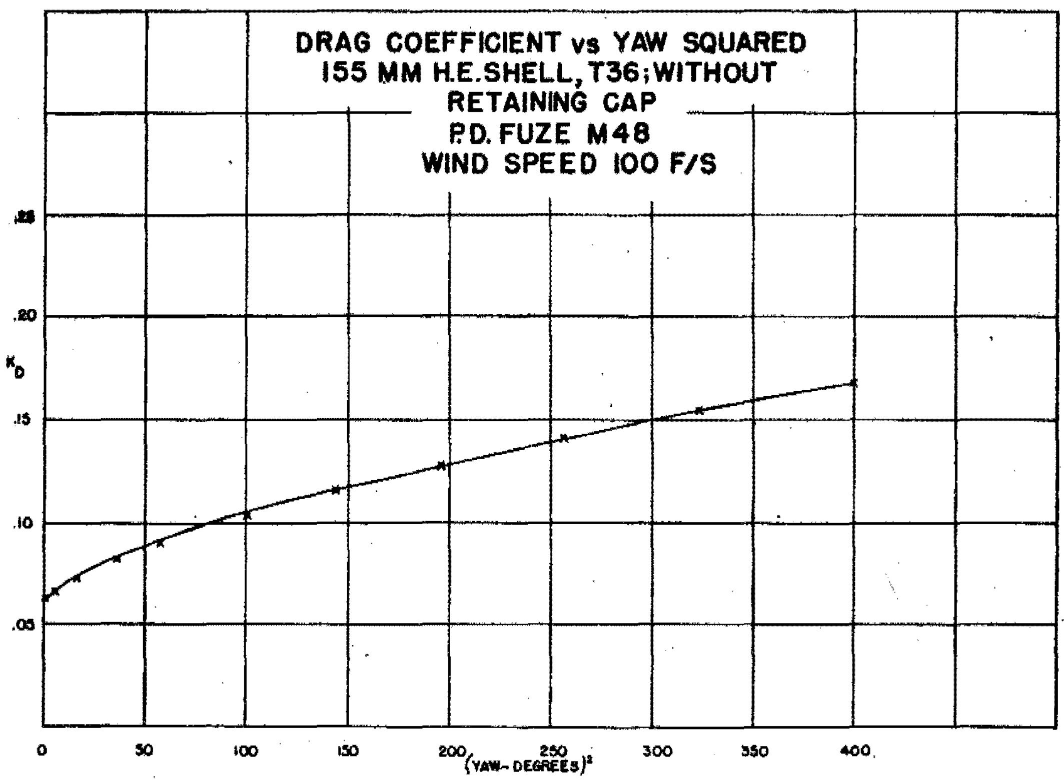

DRAG COEFFICIENT vs YAW
SHELL, H.E. 155 MM, M101 WITH
FUZE P.D. M51A1
AIR SPEED 45 FT/SEC
K_D
2.0
1.6
1.2
0.8
0.4
.0
0°
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°

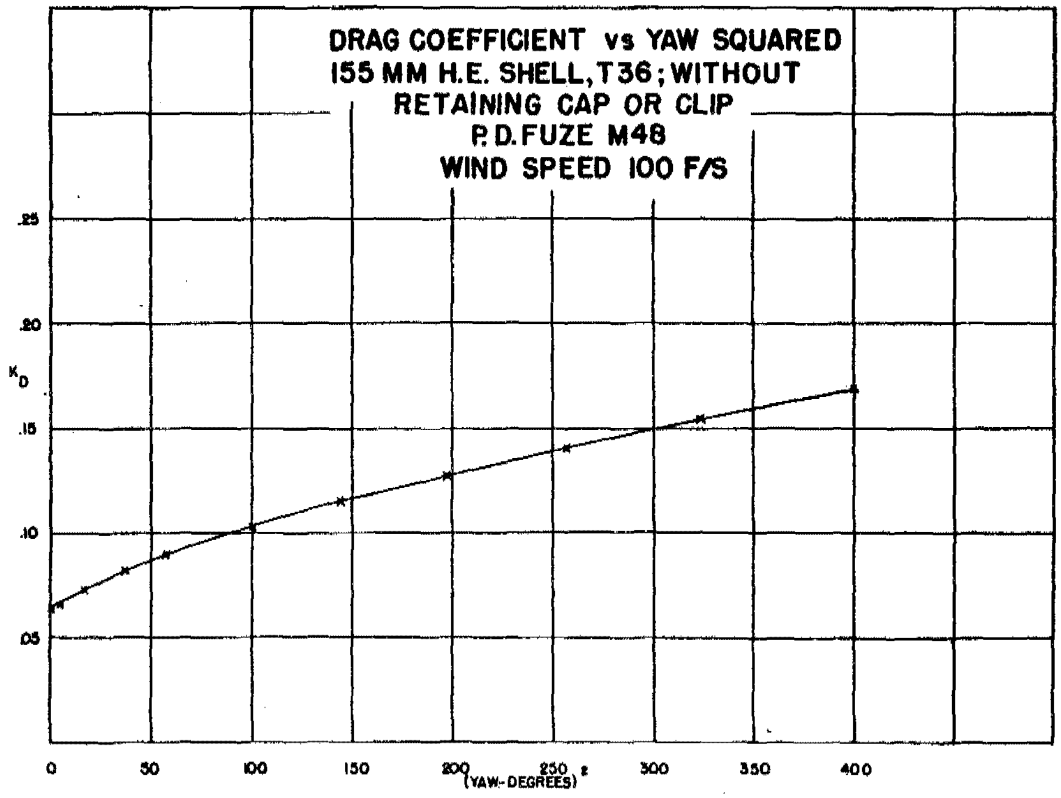

MOMENT COEFFICIENT vs YAW
SHELL, H.E., 155 MM, M101 WITH
FUZE P.D., M51A1
AIR SPEED 45 FT/SEC
$K_M \sin \delta$
1.6
1.2
.8
.4
.0
-.4
-.8
0°
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°

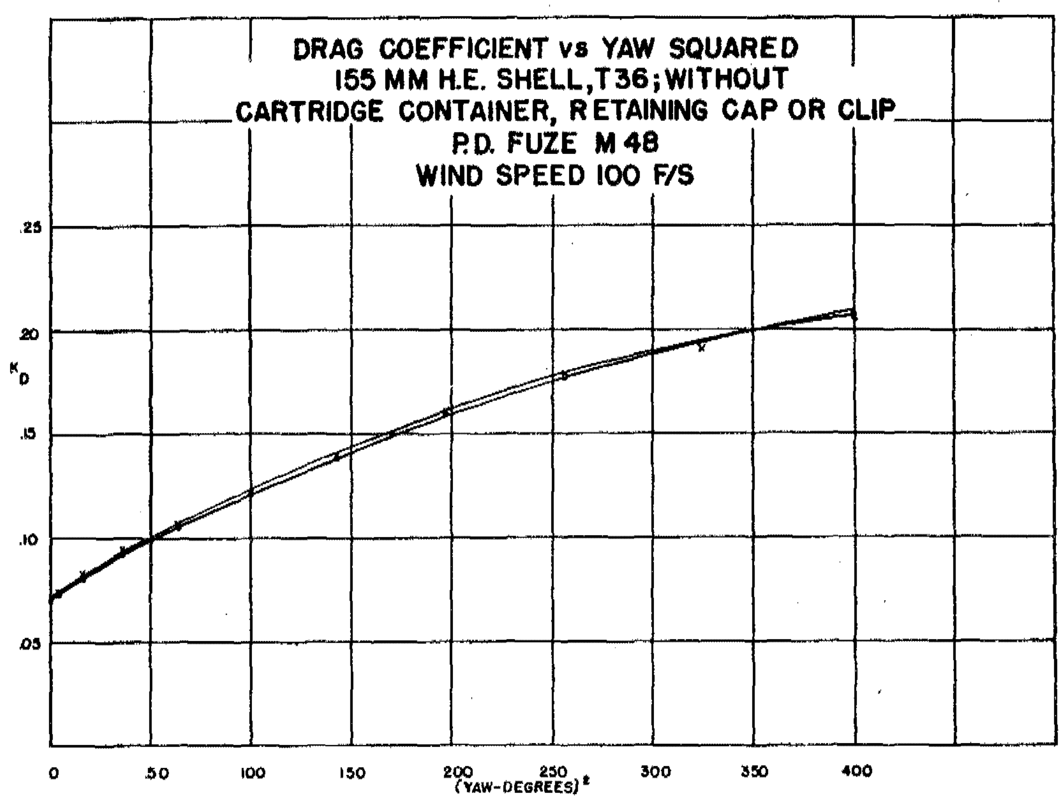

CROSS WIND FORCE COEFFICIENT vs YAW
SHELL H.E., 155 MM, M101, WITH
FUZE P.D. M51A1
AIR SPEED 45 FT/SEC
1.2
0.8
0.4
0.0
-0.4
-0.8
-1.2
K_L SIN δ
0°
20°
40°
60°
80°
δ
100°
120°
140°
160°
180°

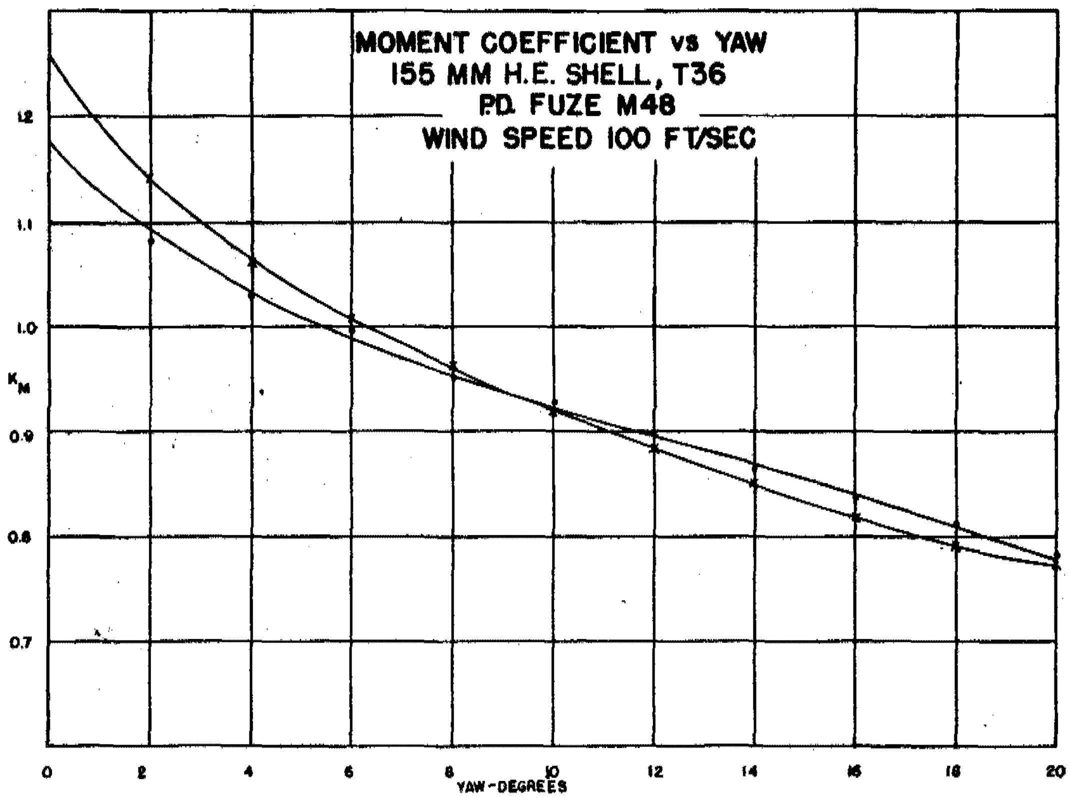

DRAG COEFFICIENT vs YAW SQUARED
155 MM H. E. SHELL, T36
P.D. FUZE M48
WIND SPEED 100 F/S
.25
.20
.15
.10
.05
K_D
0
50
100
150
200
250
300
350
400
δ² (YAW DEGREES)²

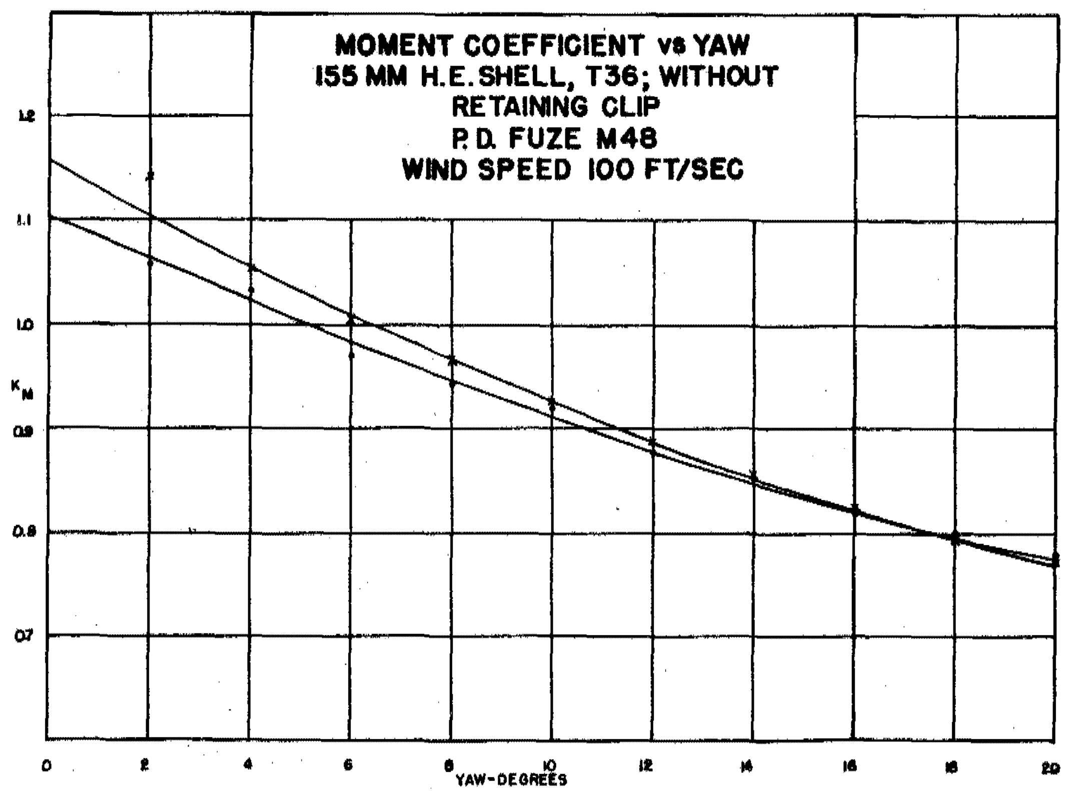

DRAG COEFFICIENT vs YAW SQUARED
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CLIP
P.D. FUZE M48
WIND SPEED 100 FT/SEC
.25
.20
K_D
.15
.10
.05
0
50
100
150
200
250
300
350
400
(YAW-DEGREES)²

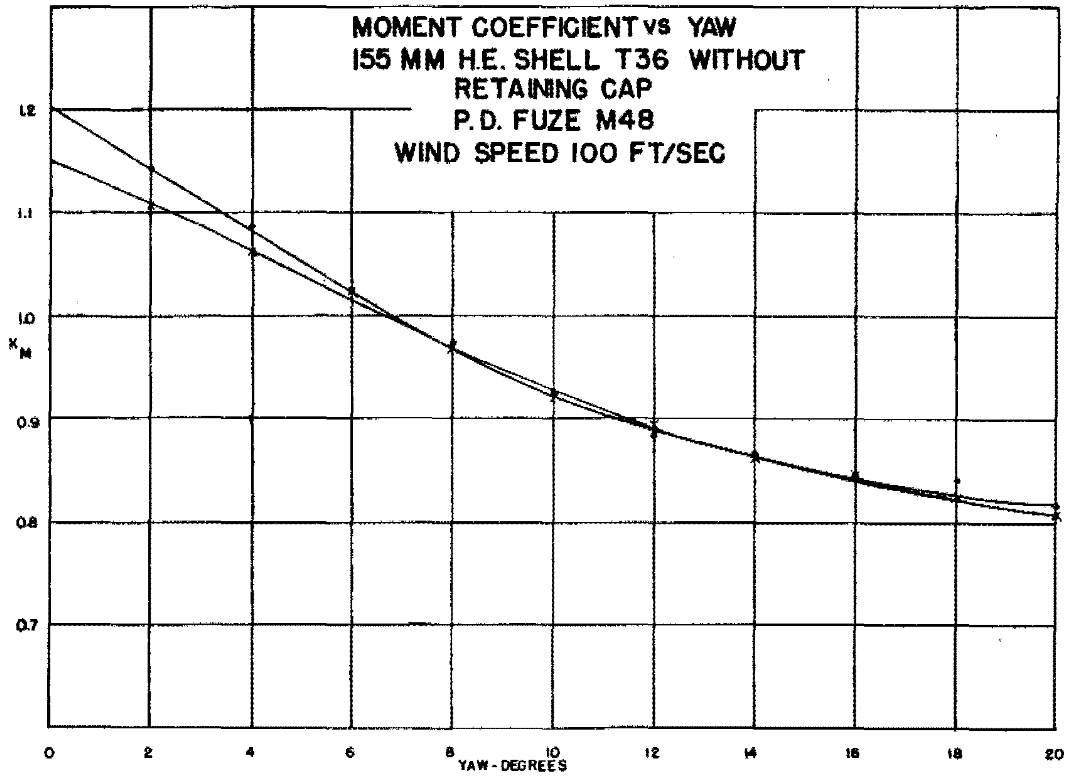

DRAG COEFFICIENT vs YAW SQUARED
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CAP
P.D. FUZE M48
WIND SPEED 100 F/S
.25
.20
K_D
.15
.10
.05
0
50
100
150
200
250
300
350
400
(YAW-DEGREES)²

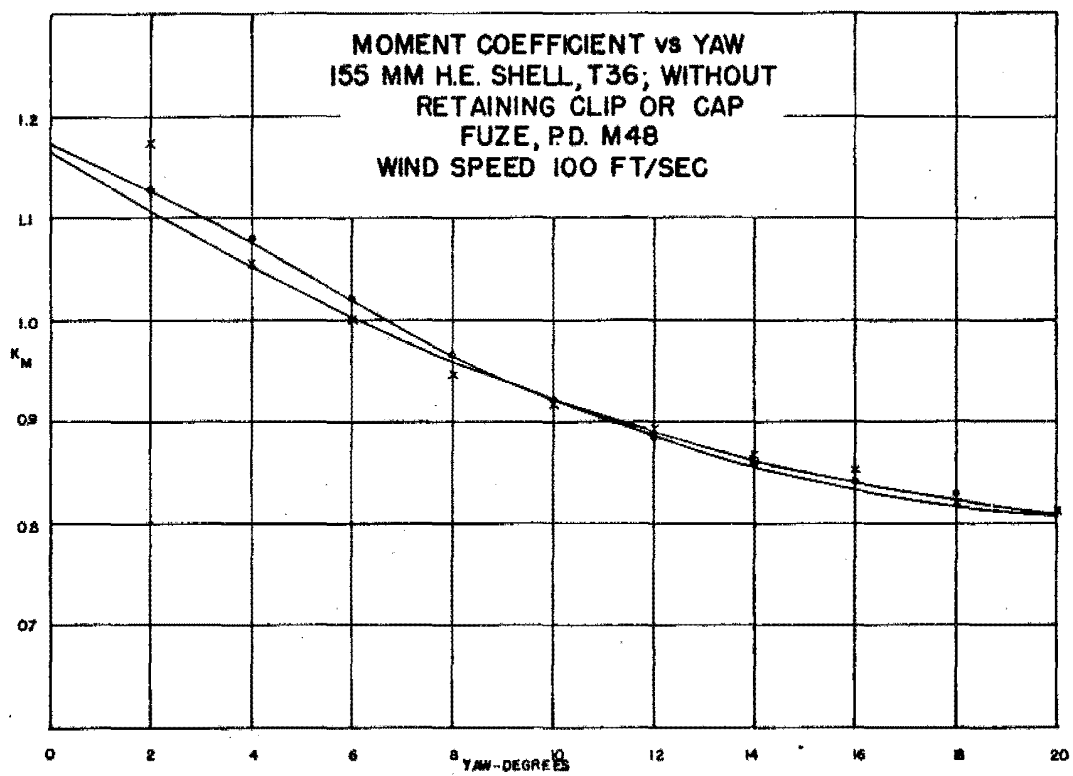

DRAG COEFFICIENT vs YAW SQUARED
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CAP OR CLIP
P.D. FUZE M48
WIND SPEED 100 F/S
.25
.20
K
D
.15
.10
.05
0
50
100
150
200
250
300
350
400
(YAW-DEGREES)²

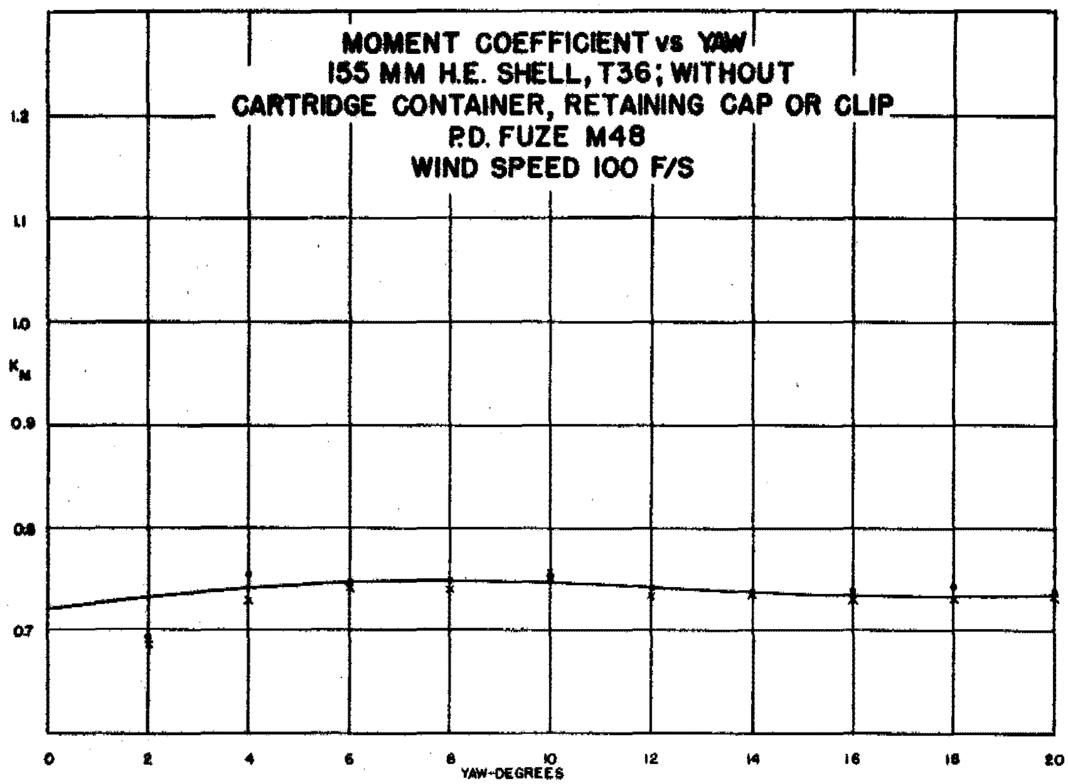

DRAG COEFFICIENT vs YAW SQUARED
155 MM H.E. SHELL, T36; WITHOUT
CARTRIDGE CONTAINER, RETAINING CAP OR CLIP
P.D. FUZE M 48
WIND SPEED 100 F/S
.25
.20
K
D
.15
.10
.05
0
50
100
150
200
250
300
350
400
(YAW-DEGREES)²

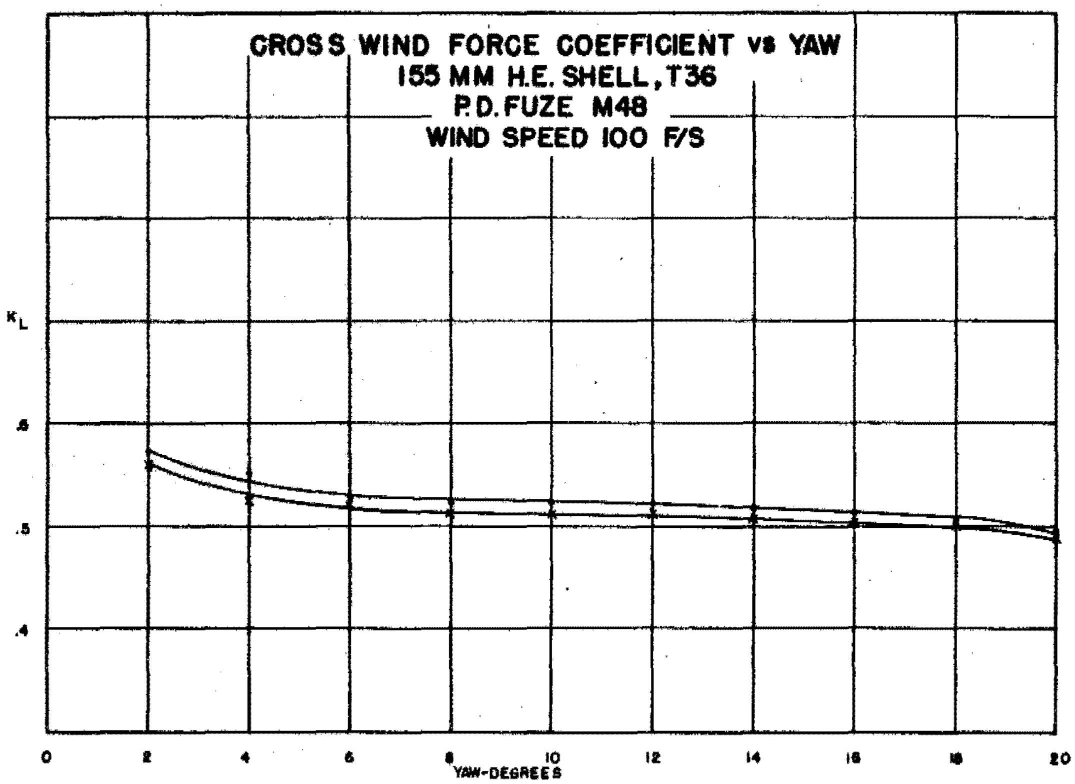

MOMENT COEFFICIENT vs YAW
155 MM H.E. SHELL, T36
P.D. FUZE M48
WIND SPEED 100 FT/SEC
1.2
1.1
1.0
KM
0.9
0.8
0.7
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

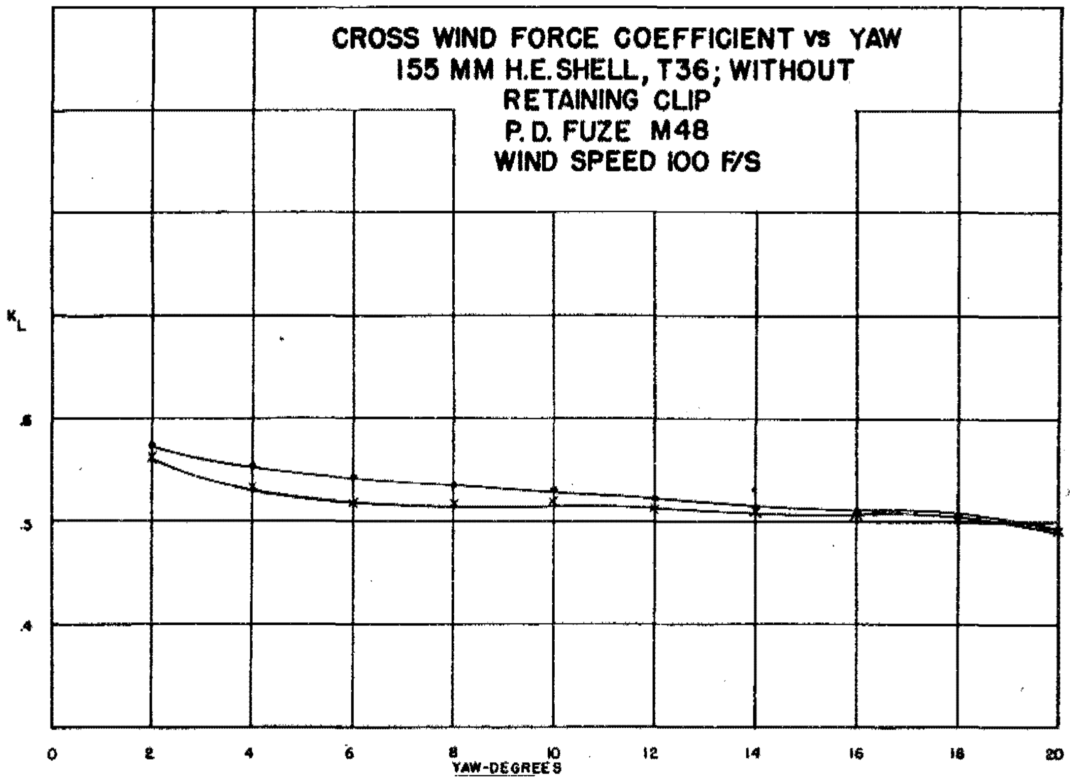

MOMENT COEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CLIP
P.D. FUZE M48
WIND SPEED 100 FT/SEC
1.2
1.1
1.0
KM
0.9
0.8
0.7
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

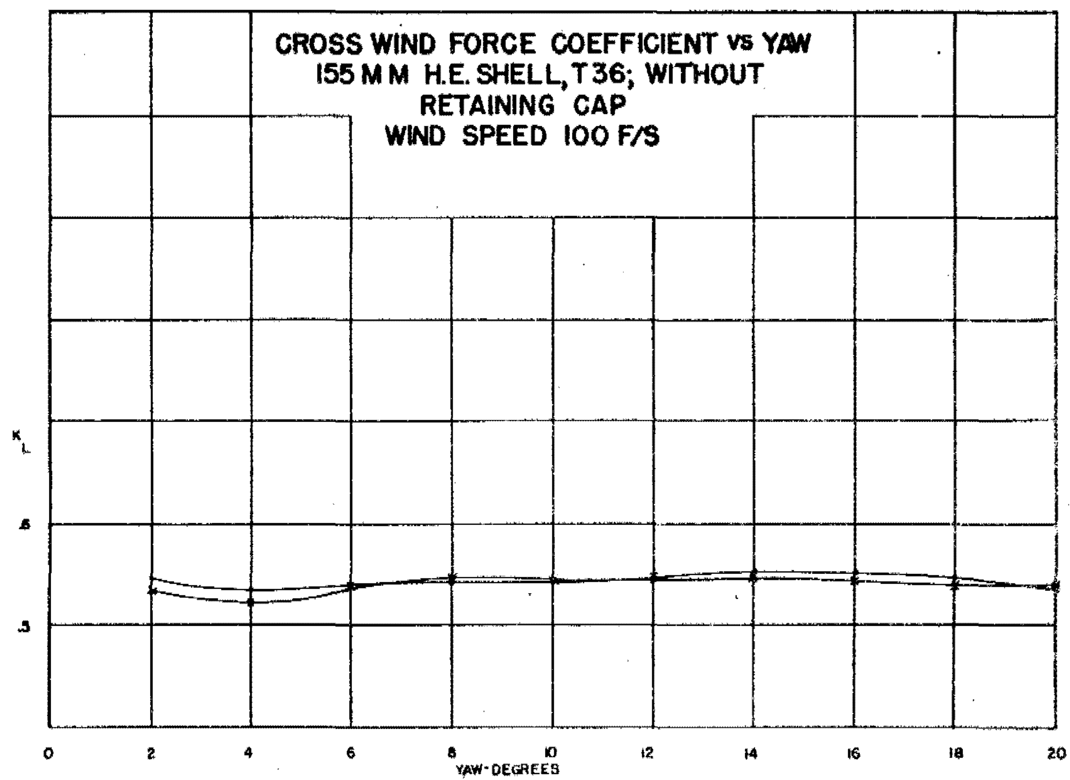

MOMENT COEFFICIENT vs YAW
155 MM H.E. SHELL T36 WITHOUT
RETAINING CAP
P.D. FUZE M48
WIND SPEED 100 FT/SEC
1.2
1.1
1.0
K_M
0.9
0.8
0.7
0
2
4
6
8
10
12
14
16
18
20
YAW - DEGREES

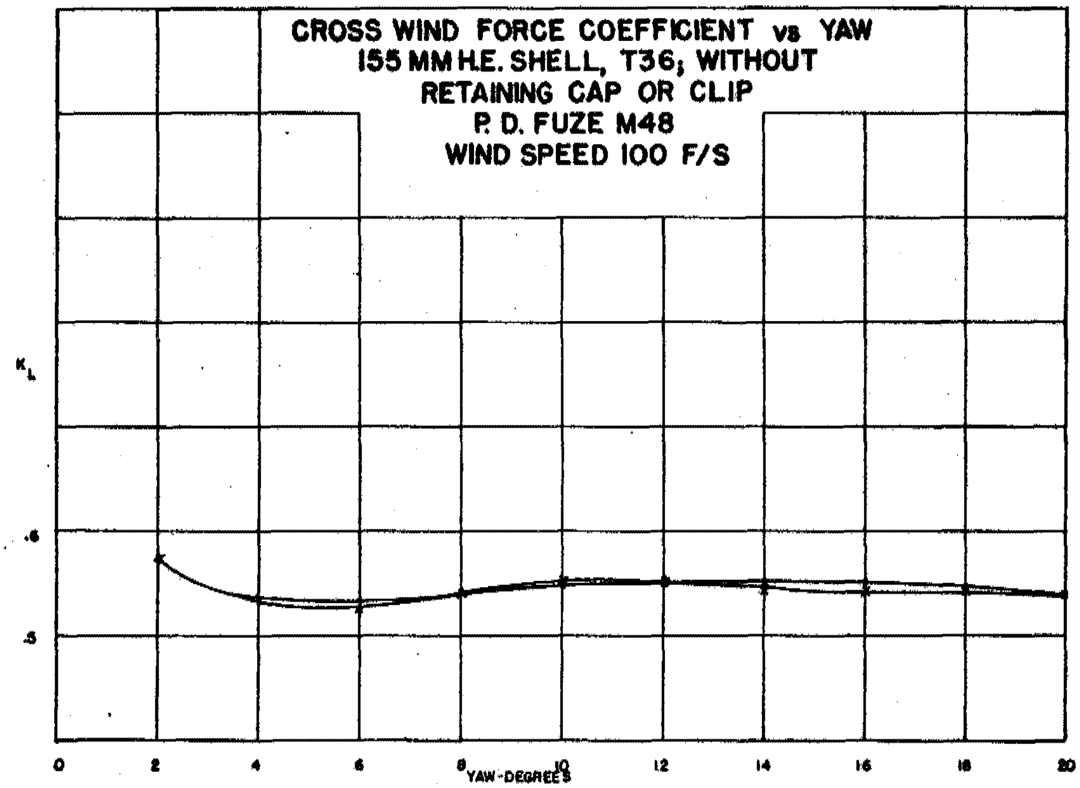

MOMENT COEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CLIP OR CAP
FUZE, P.D. M48
WIND SPEED 100 FT/SEC
1.2
1.1
1.0
K_M
0.9
0.8
0.7
0
2
4
6
8
10
12
14
16
18
20
YAW - DEGREES

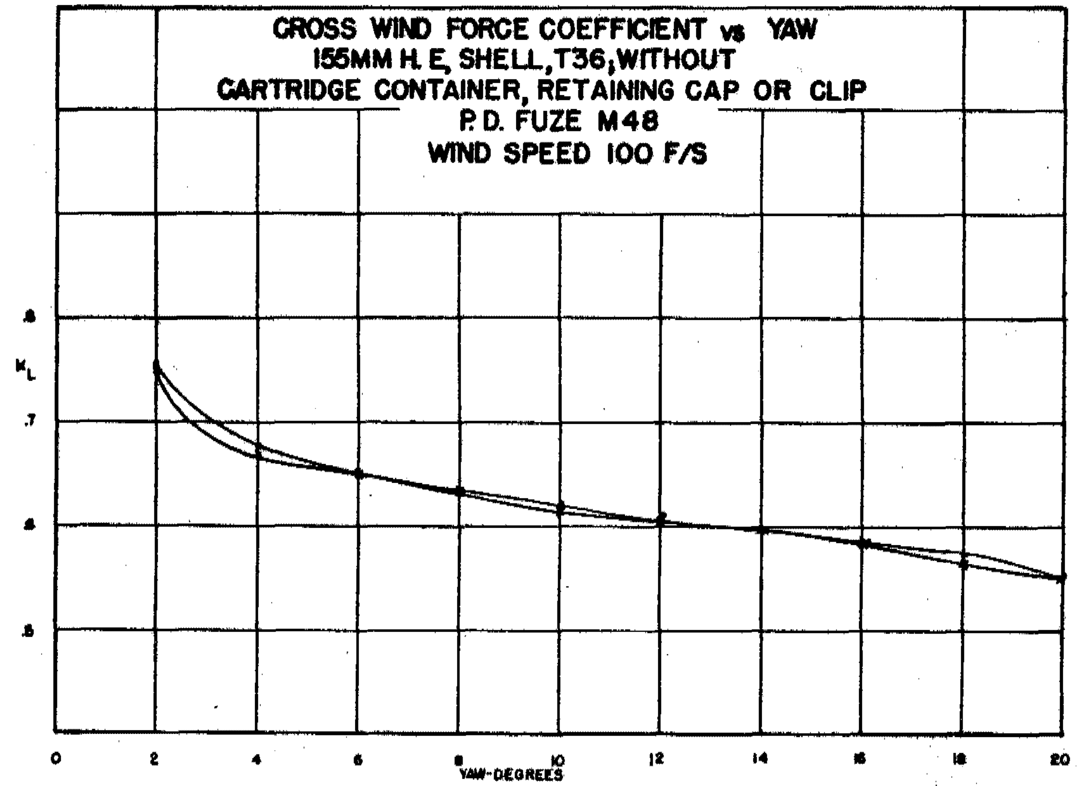

MOMENT COEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
CARTRIDGE CONTAINER, RETAINING CAP OR CLIP
P.D. FUZE M48
WIND SPEED 100 F/S
1.2
1.1
1.0
K_M
0.9
0.8
0.7
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

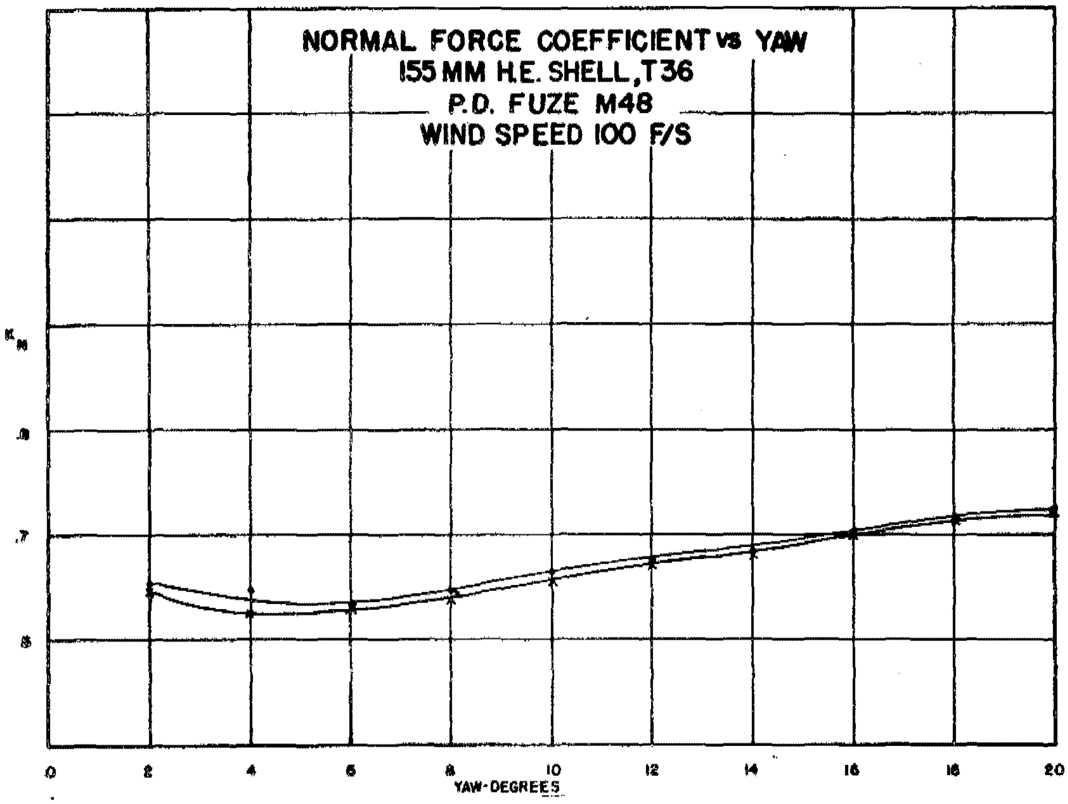

CROSS WIND FORCE COEFFICIENT vs YAW
155 MM H.E. SHELL, T36
P.D. FUZE M48
WIND SPEED 100 F/S
K_L
.6
.5
.4
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

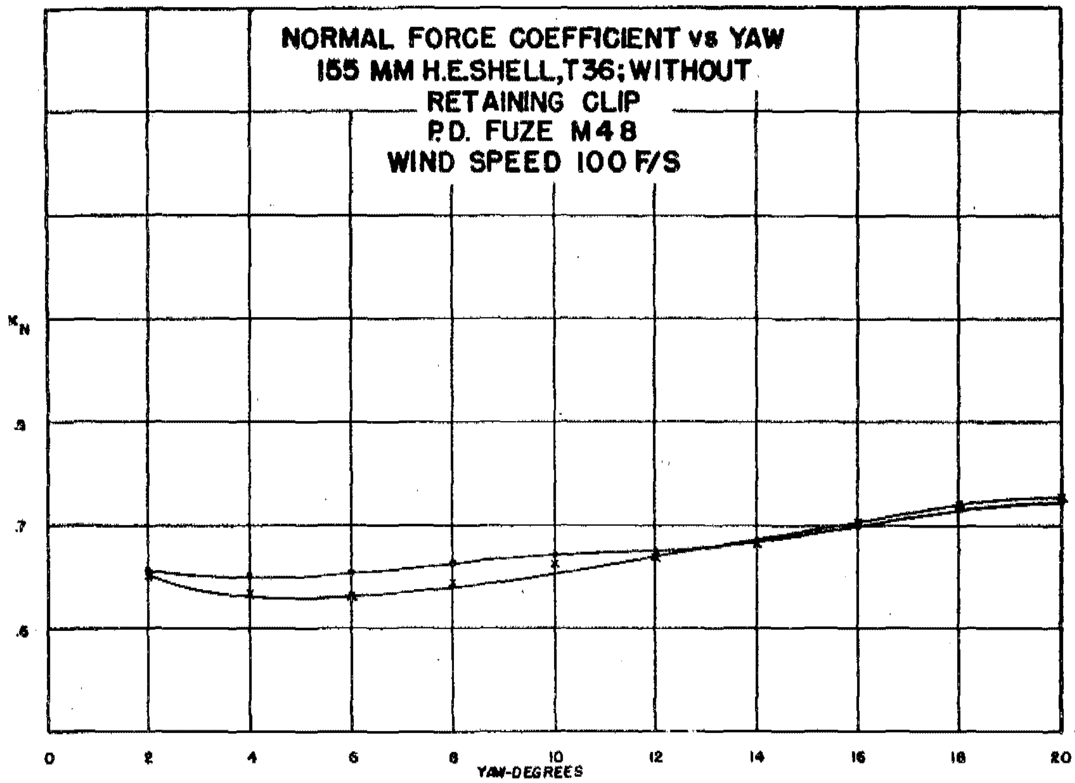

CROSS WIND FORCE COEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CLIP
P.D. FUZE M48
WIND SPEED 100 F/S
K_L
.6
.5
.4
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

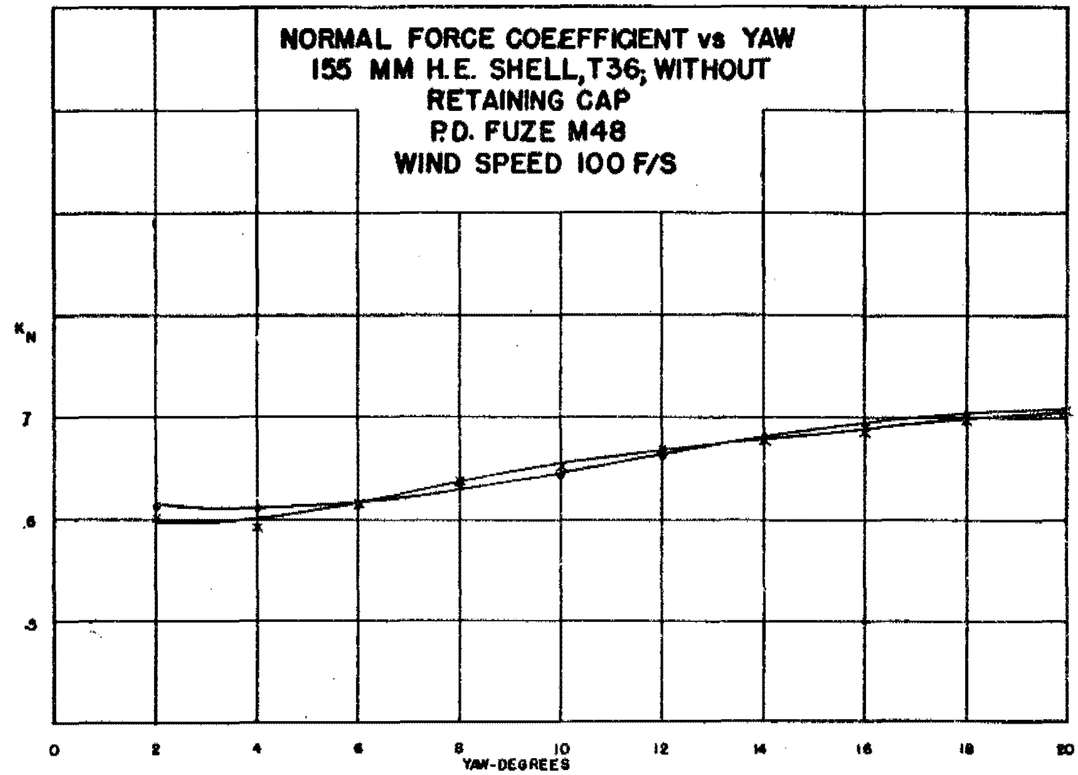

CROSS WIND FORCE COEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CAP
WIND SPEED 100 F/S
K_L
.6
.5
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

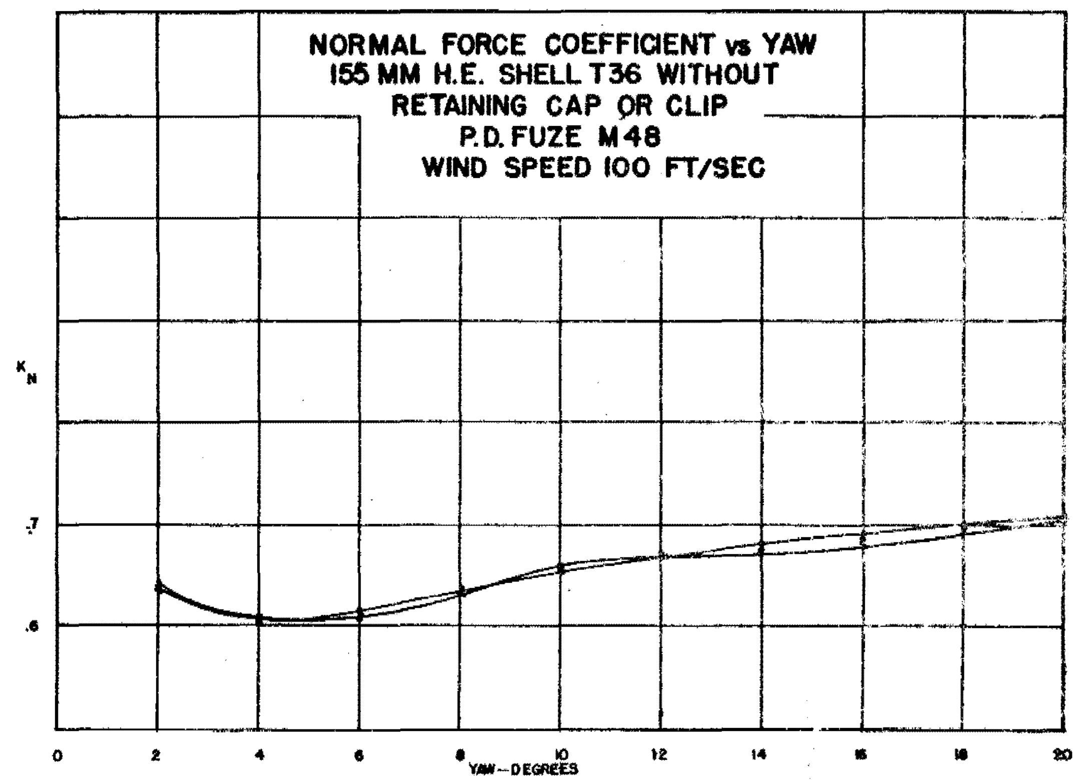

CROSS WIND FORCE COEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CAP OR CLIP
P. D. FUZE M48
WIND SPEED 100 F/S
KL
.6
.5
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

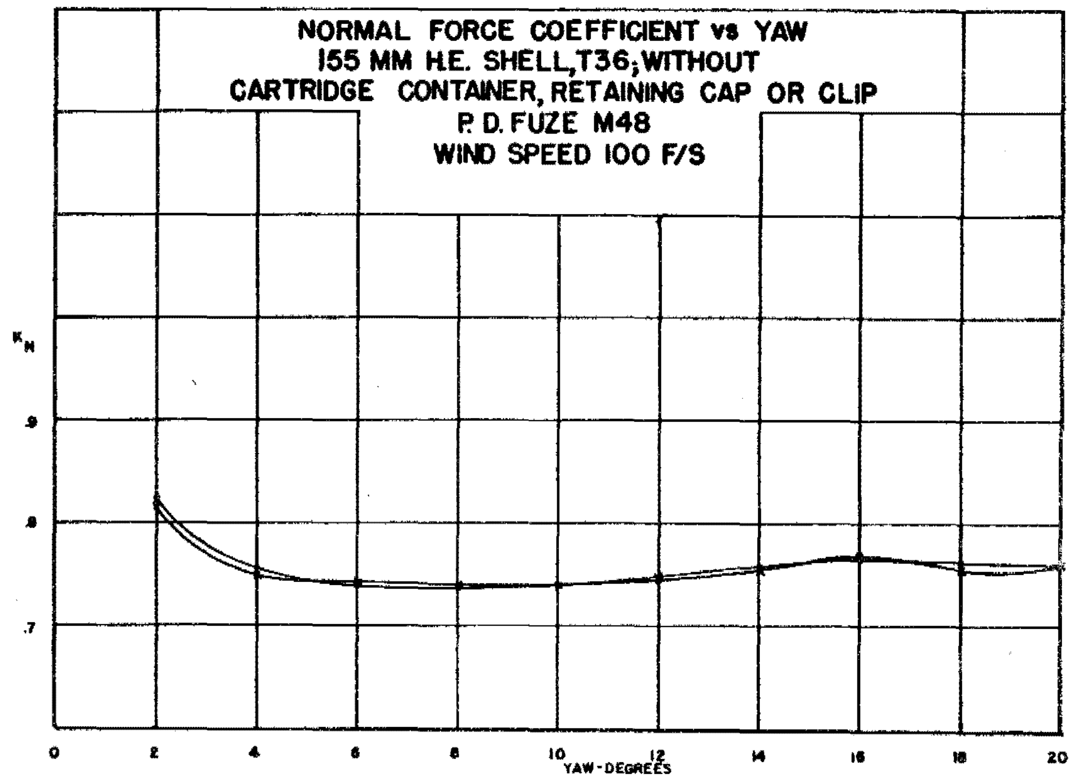

CROSS WIND FORCE COEFFICIENT vs YAW
155MM H. E. SHELL, T36; WITHOUT
CARTRIDGE CONTAINER, RETAINING CAP OR CLIP
P. D. FUZE M48
WIND SPEED 100 F/S
.8
KL
.7
.6
.5
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

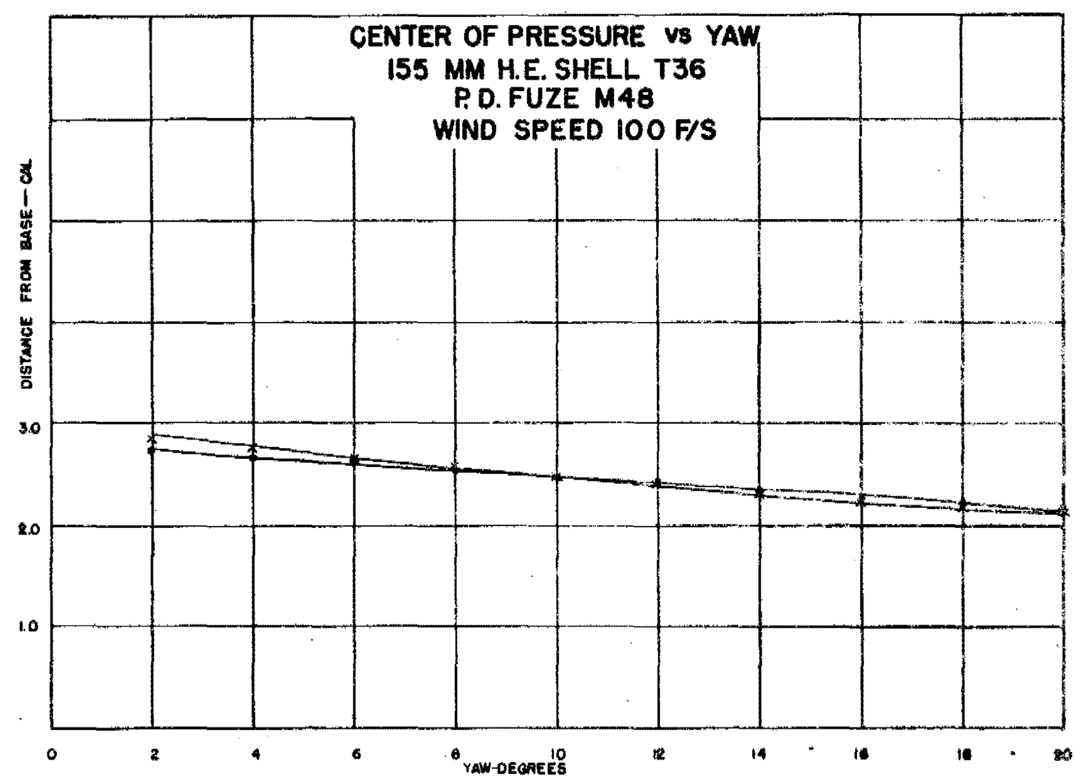

NORMAL FORCE COEFFICIENT vs YAW
155 MM H.E. SHELL, T36
P.D. FUZE M48
WIND SPEED 100 F/S
K_N
.8
.7
.6
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

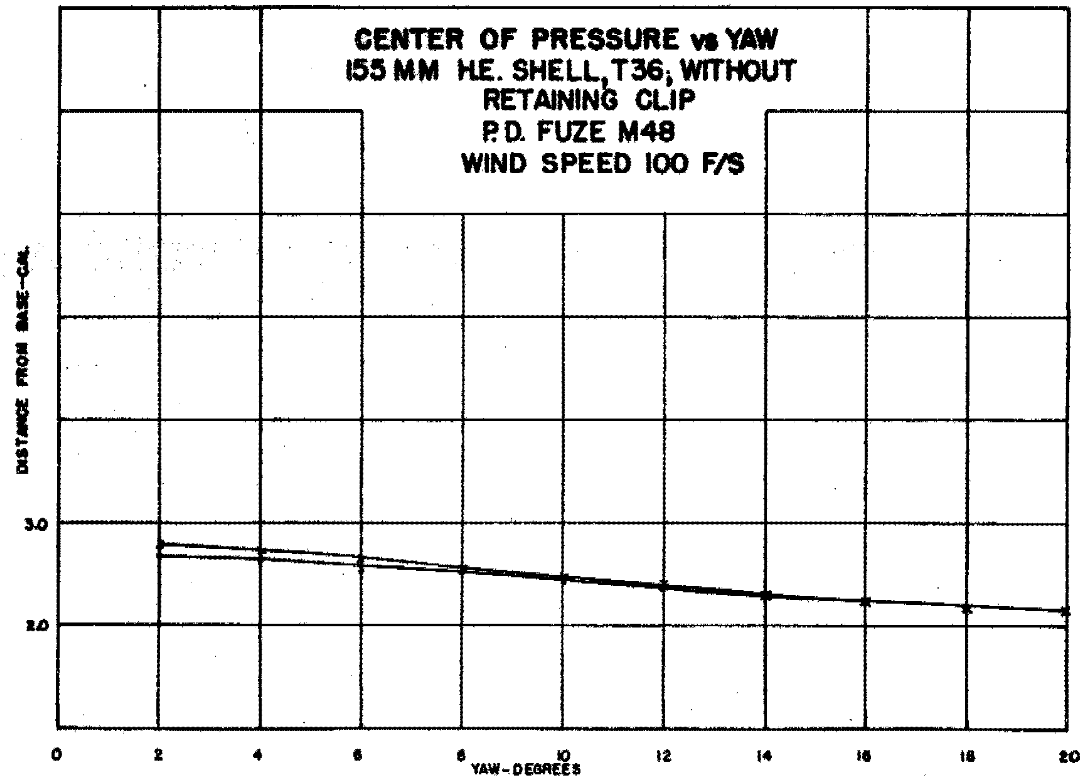

NORMAL FORCE COEFFICIENT vs YAW
155 MM H.E.SHELL,T36; WITHOUT
RETAINING CLIP
P.D. FUZE M48
WIND SPEED 100 F/S
K_N
.8
.7
.6
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

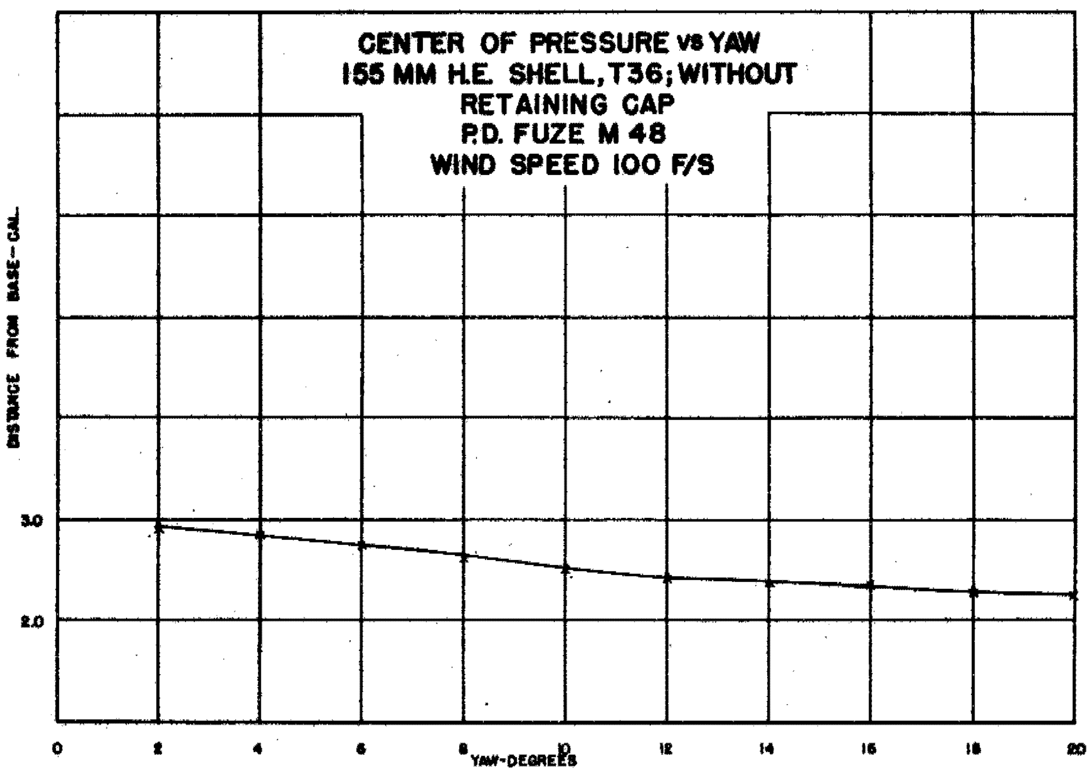

NORMAL FORCE COEEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CAP
P.D. FUZE M48
WIND SPEED 100 F/S
K_N
.7
.6
.5
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

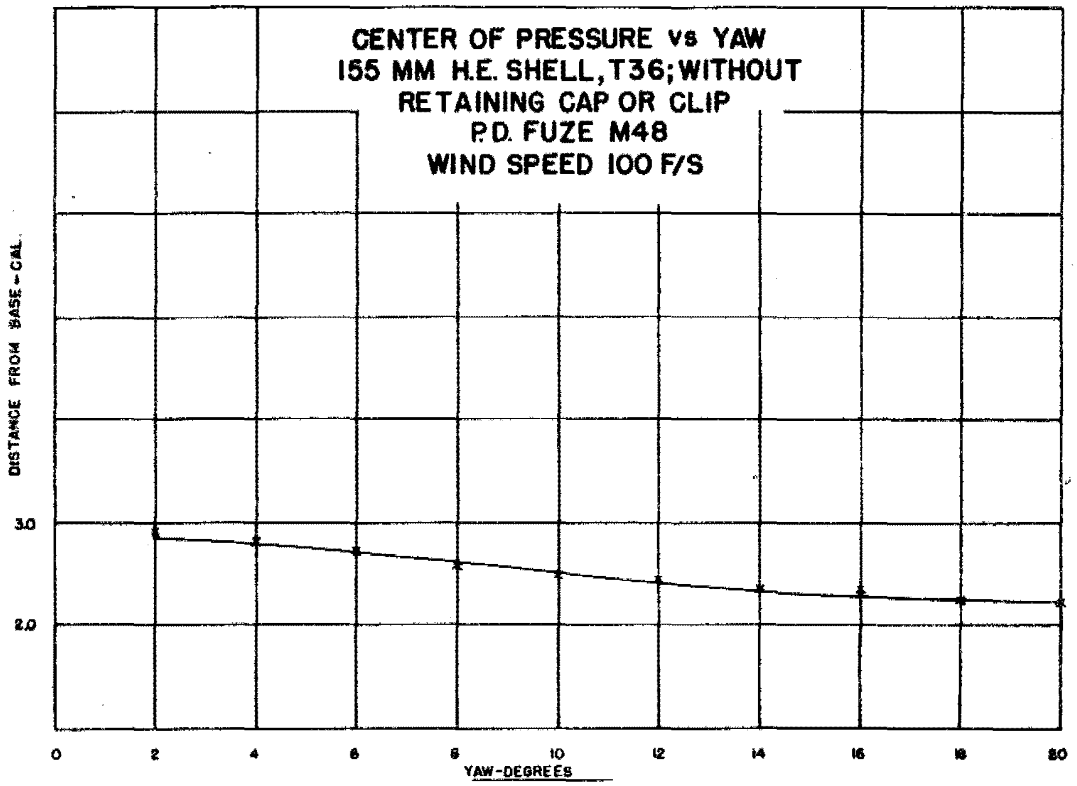

NORMAL FORCE COEFFICIENT vs YAW
155 MM H.E. SHELL T36 WITHOUT
RETAINING CAP OR CLIP
P.D. FUZE M48
WIND SPEED 100 FT/SEC
K_N
.7
.6
0
2
4
6
8
10
12
14
16
18
20
YAW—DEGREES

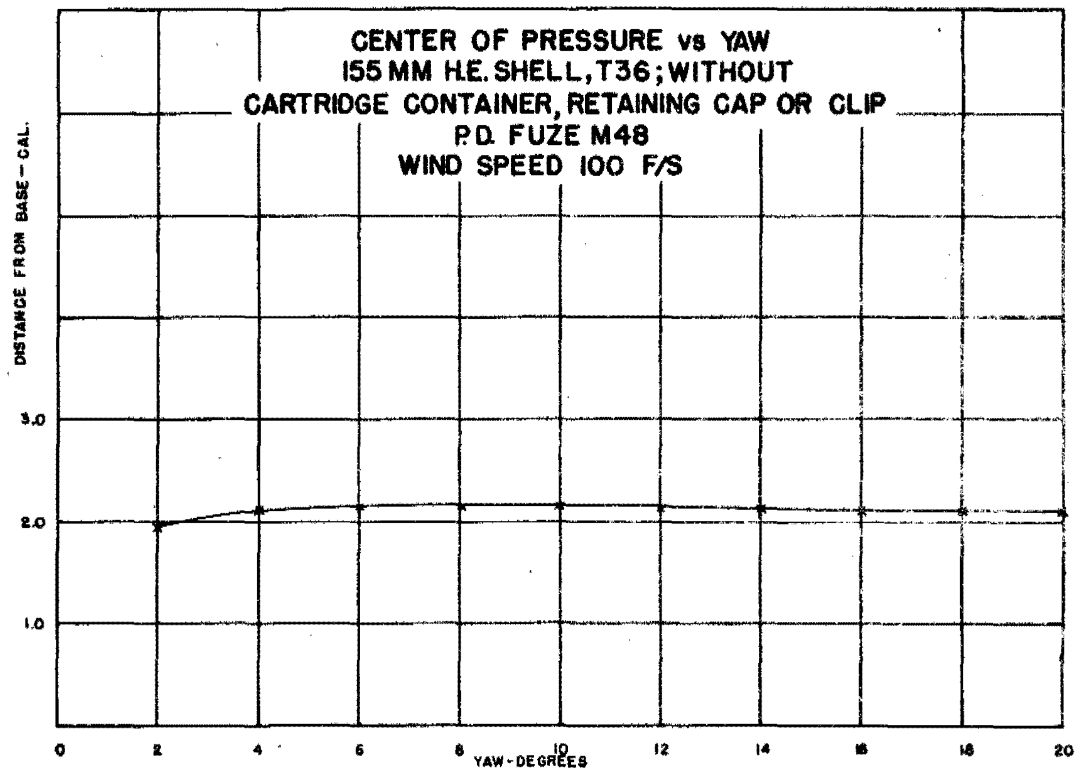

NORMAL FORCE COEFFICIENT vs YAW
155 MM H.E. SHELL, T36; WITHOUT
CARTRIDGE CONTAINER, RETAINING CAP OR CLIP
P. D. FUZE M48
WIND SPEED 100 F/S
K_N
.9
.8
.7
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

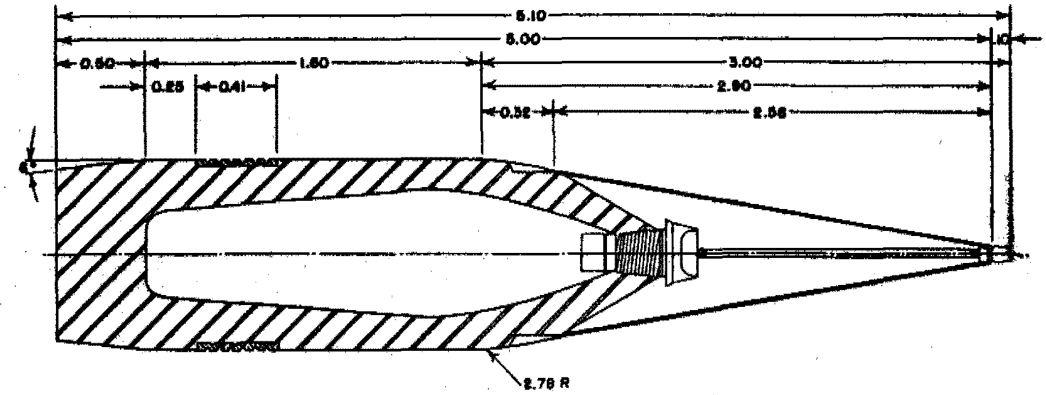

CENTER OF PRESSURE vs YAW
155 MM H.E. SHELL T36
P. D. FUZE M48
WIND SPEED 100 F/S
DISTANCE FROM BASE — CAL
3.0
2.0
1.0
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES


CENTER OF PRESSURE vs YAW
155 MM H.E. SHELL, T36; WITHOUT RETAINING CLIP
P.D. FUZE M48
WIND SPEED 100 F/S
DISTANCE FROM BASE-CAL.
3.0
2.0
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

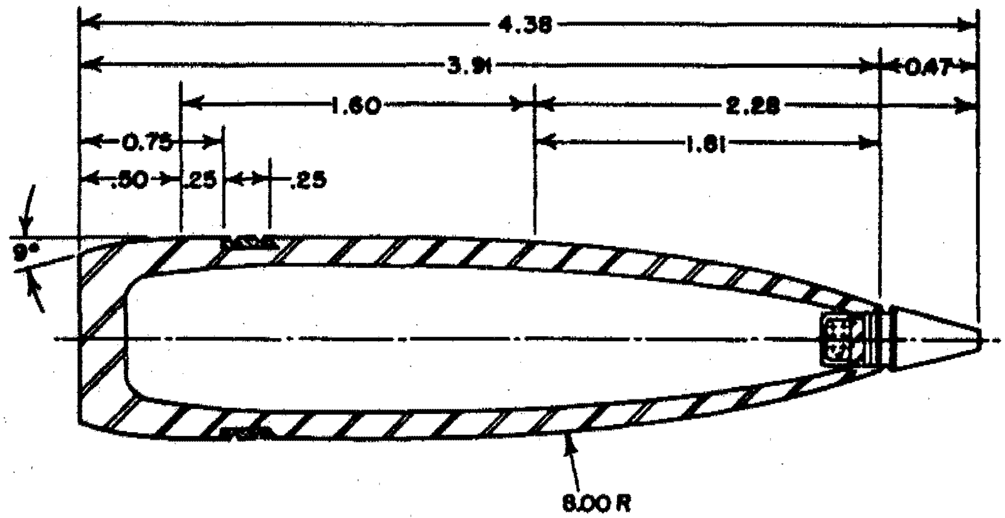

CENTER OF PRESSURE vs YAW
155 MM H.E. SHELL, T36; WITHOUT RETAINING CAP
P.D. FUZE M 48
WIND SPEED 100 F/S
DISTANCE FROM BASE-CAL.
3.0
2.0
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES


CENTER OF PRESSURE vs YAW
155 MM H.E. SHELL, T36; WITHOUT
RETAINING CAP OR CLIP
P.D. FUZE M48
WIND SPEED 100 F/S
DISTANCE FROM BASE - CAL.
3.0
2.0
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES

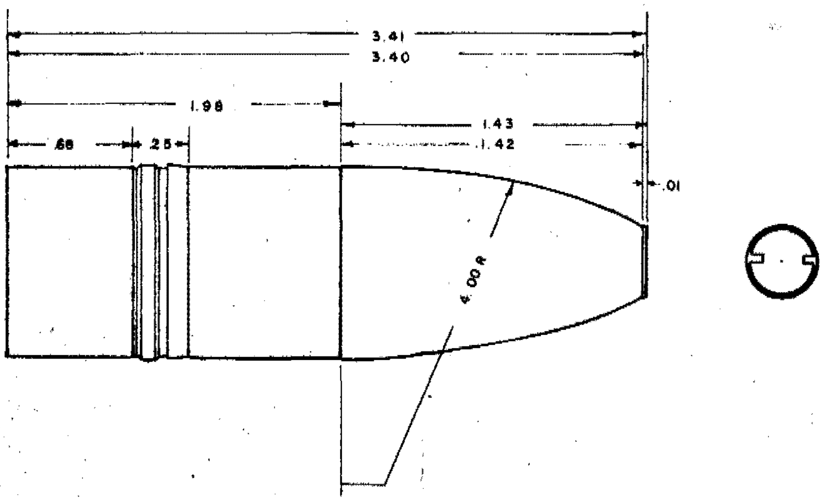

CENTER OF PRESSURE vs YAW
155 MM H.E. SHELL, T36; WITHOUT
CARTRIDGE CONTAINER, RETAINING CAP OR CLIP
P.D. FUZE M48
WIND SPEED 100 F/S
DISTANCE FROM BASE - CAL.
3.0
2.0
1.0
0
2
4
6
8
10
12
14
16
18
20
YAW-DEGREES



SHELL, 8", H.E., M103; FUZE, P.D., M51A1, MOD. 1



SHELL, 8", H.E., M106; FUZE, P.D., M51



PROJECTILE, PROOF, 8", T9; CIRCULAR PLUG

ALL DIMENSIONS IN CALIBERS

20. 8-inch Projectiles

a. Drawings

Shell, High Explosive, M103 (T2)	75-4-87
Shell, High Explosive, M106	75-4-76
Projectile, Proof, T9 (Modification of H.E. Shell Mark 1)	GA 1757 and 75-4-23
Fuze, Point Detonating, M51	73-2-145
Fuze, Point Detonating, M51 Modification 1	73-2-163 Rev. 1
Fuze, Experimental, National Defense Research Committee (Same contour as M51 Fuze)	

b. Physical Characteristics

Projectile	Fuze	Weight Lb.	No. of Rds.	g cal	A lb.ft.^{2}	B lb.ft.^{2}
H.E. M103	M51 Mod. 1	240	20	1.450	15.23	104.43
H.E. M106	M51	200				
Proof T9	{Circular Plug}	200				

c. Drag

Projectile	Fuze	Report	Observation	Proj. Type	Form Factor	Velocity ft/sec.	K_D
H.E. M106	M51	BRL 284 Aug 42	Resist.	5	0.86	815	.049
					0.92	1370	.157
					0.79	1940	.130
Proof T9	{Circular Plug}	BRL 284 Aug 42	Resist.	1	0.53	820	.047
					0.43	1380	.109

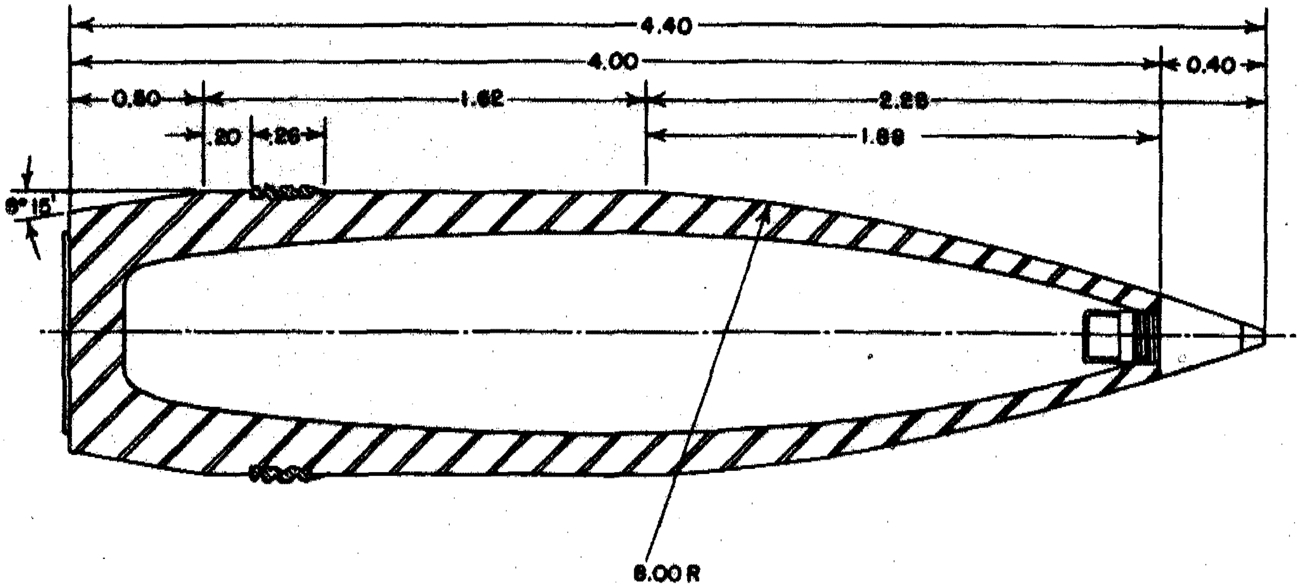
d. Stability

Shell	H.E. M103
Fuze	M51 Mod. 1
Report	BRL 380
No. of Rds.	4
Velocity	2150 ft/sec
n	25 cal
s	2.34
K_M	1.515

e. Spin

Shell	H.E. M106
Fuze	N.D.R.C.
S'/d^2	10.6
Report	BRL 408
No. of Rds.	2
Gun	M1E1 (n=25)
Muzzle Velocity	1950 ft/sec
Reynold's No.	6.10×10^6
K_A	0.0043
C'_{DF}	0.00172

21. 240mm Projectiles



SHELL, 240MM, H.E., M114; FUZE, P.D., M51 **ALL DIMENSIONS IN CALIBERS**

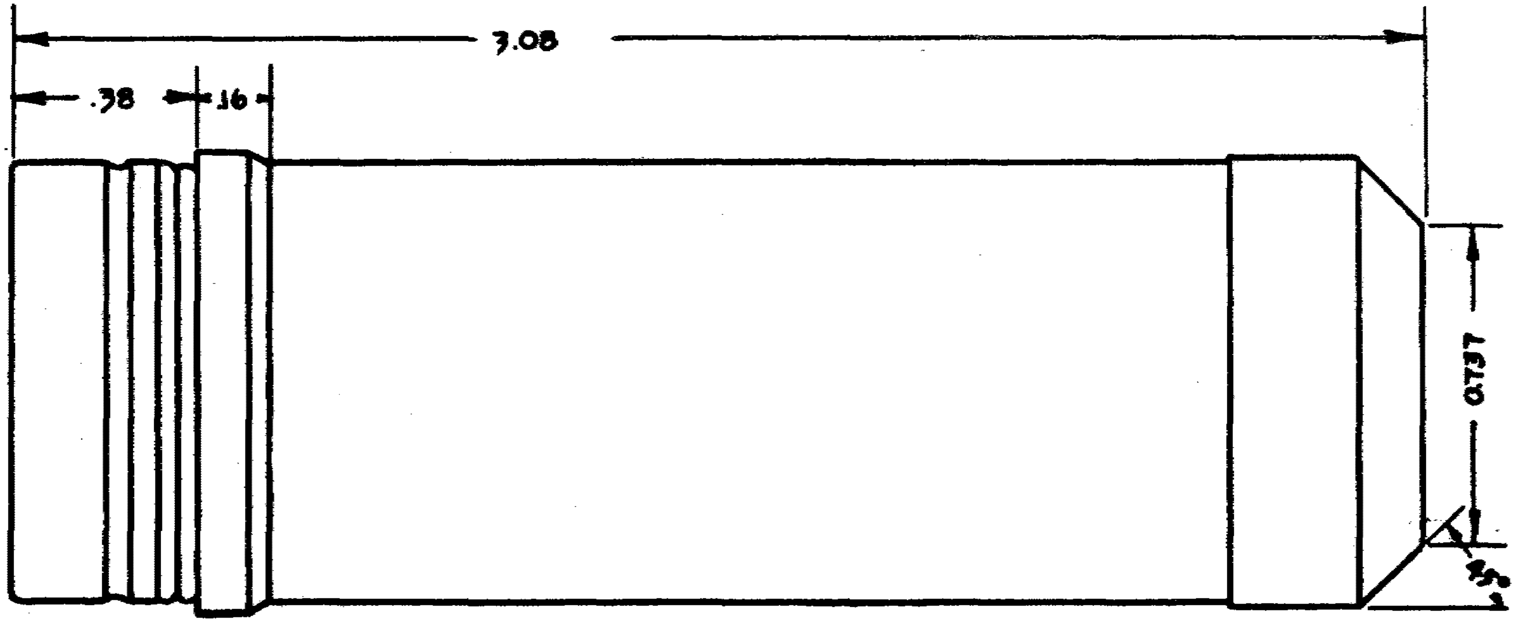
a. Drawing

Shell, High Explosive, M114 75-4-92

Fuze, Experimental, National Defense Research Committee (same contour as M51 Fuze)

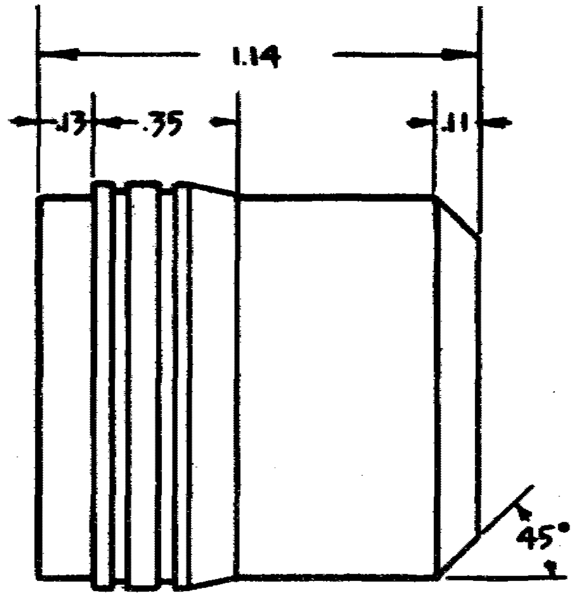
b. Spin

Shell	H.E. M114
Fuze	N.D.R.C.
Weight	360 lb.
S'/d^2	10.7
Report	BRL 408
No. of Rds.	6
Howitzer	M1(T1)
Caliber	9.449 in.
n	25
Muzzle Velocity	1500 and 2300 ft/sec
Reynold's No.	7.48×10^6
K_A	0.0026
C'_{DF}	0.00097

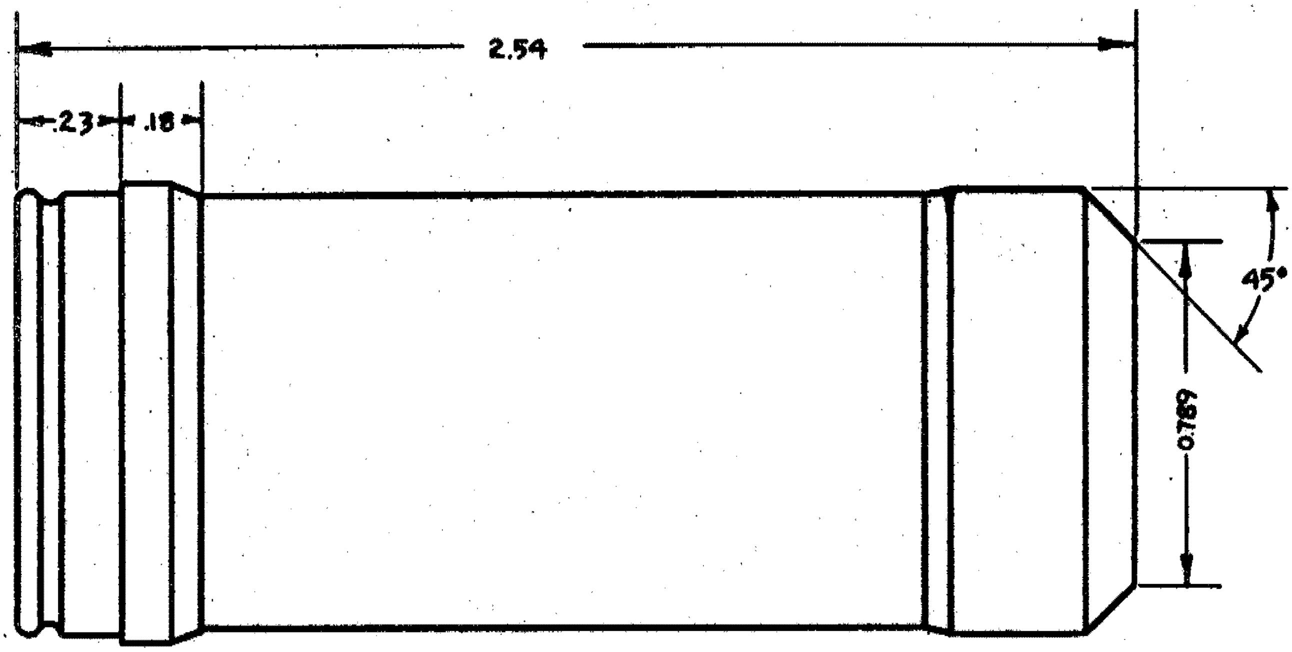


SLUG, 15.96-LB., 75MM, MARK I

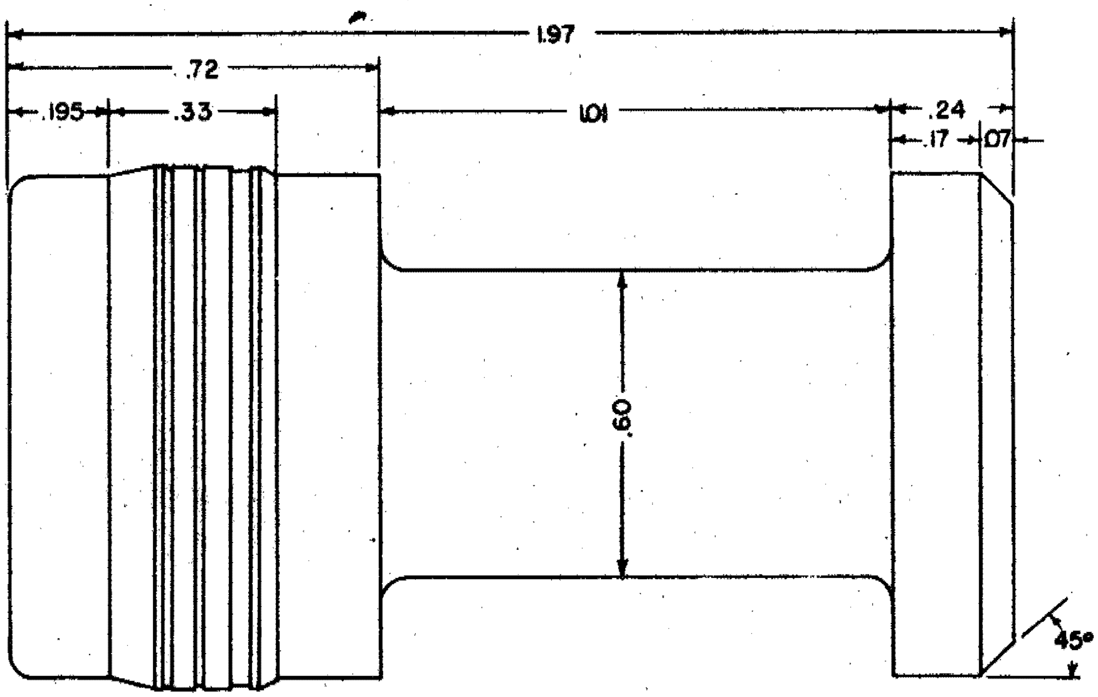
ALL DIMENSIONS IN CALIBERS



SLUG, 2.4-LB., 57MM



SLUG, 15-LB., 3-INCH, MARK I



PROJECTILE, PROOF, 155MM SIMULATING THE H.V.A.P. SHOT T35

ALL DIMENSIONS IN CALIBERS

22. Drag of Slugs

a. Slugs with 45° bevel

Resistance firings made with 37mm, 75mm and 3-in. Slugs, at velocity from 1450 to 2700 ft/sec.

Illustration: 75mm 15.96 lb. Slug Mark 1
Reports: O.P. 4866 BRL 289
Graph: K_D vs. M

b. 57mm 2.4 lb. Slug

Resistance firings at velocities from 2890 to 4325 ft/sec

Reports: BRL 289, Memo Apr 42, Memo Nov 42
Drg. (Fig. 4, BRL 289)
Graph: K_D vs. M

c. 3-inch 15 lb. Slug Mark 1

Resistance firings at velocities from 600 to 2900 ft/sec

Reports: O.P. 4866, BRL 289
Graph: K_D vs. M

d. 155mm Proof Projectile

Simulating the H.V.A.P. Shot T35

Weight 58.8 lb.
Resistance firings

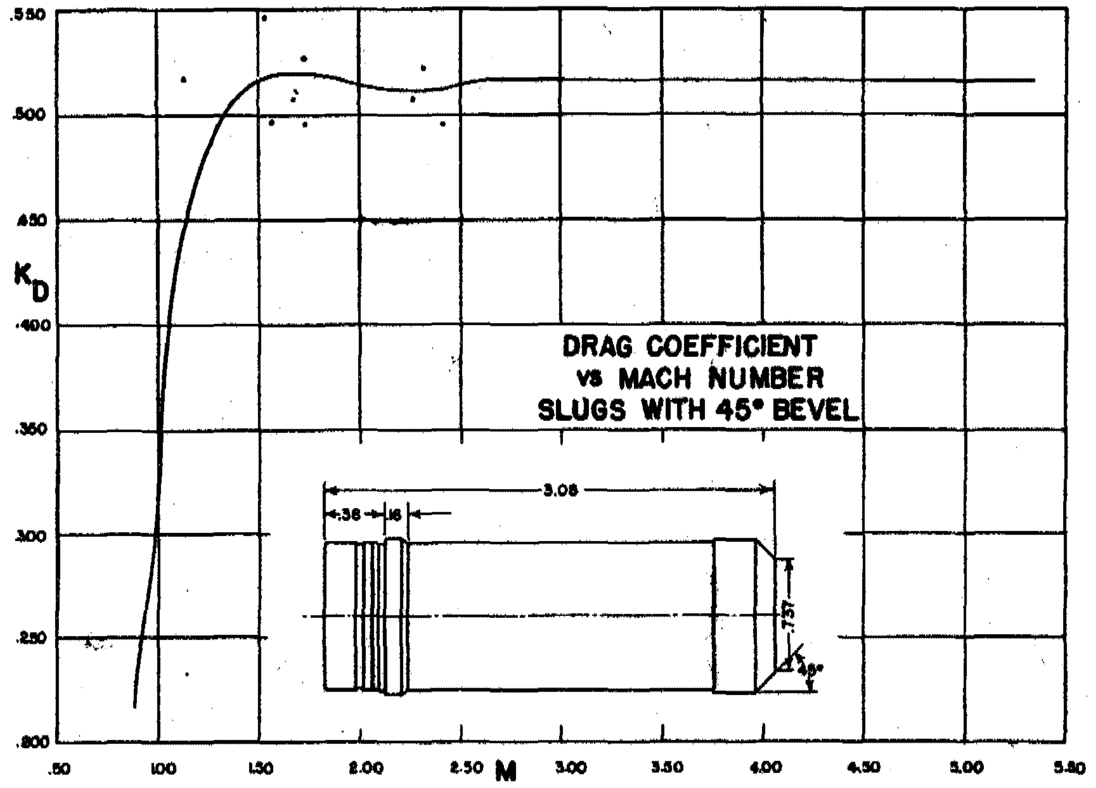
Memo	Mar 45	May 45
Form Factor (i)	2.36	2.5
Velocity (ft/sec)	2620	3225
Drag Coef (K_D)	0.513	0.508

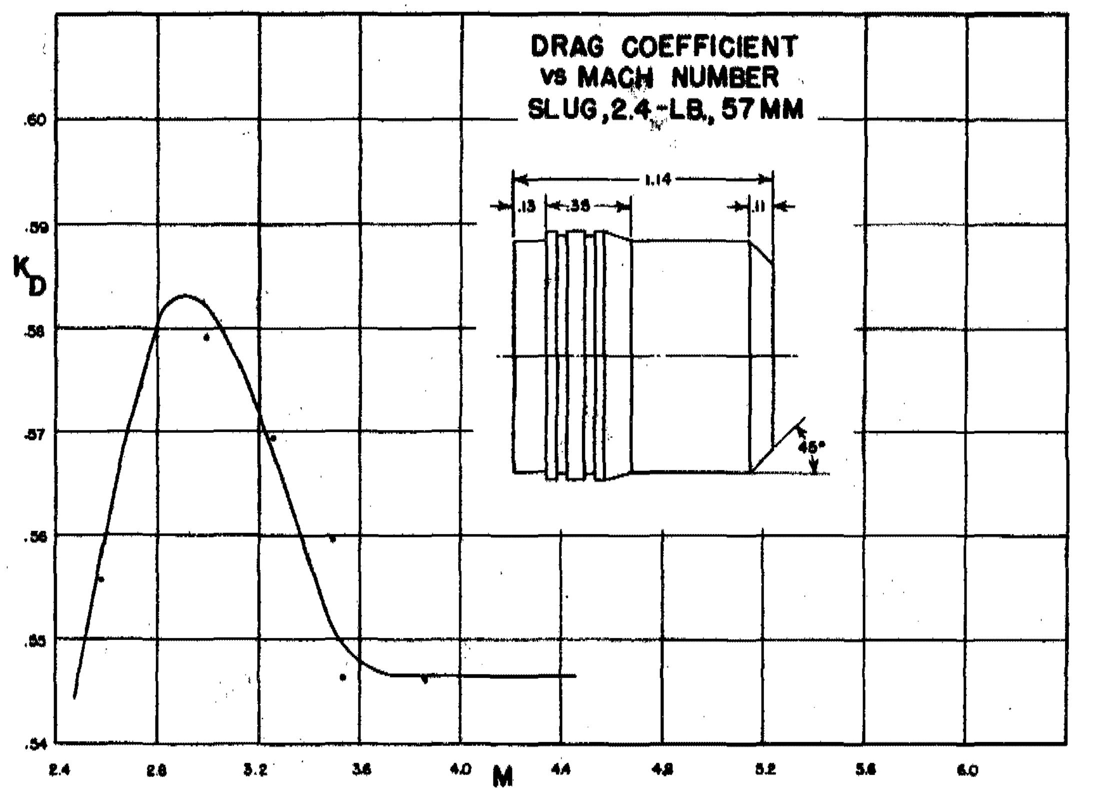
e. 40mm 2.375 lb. Flat Head Shot

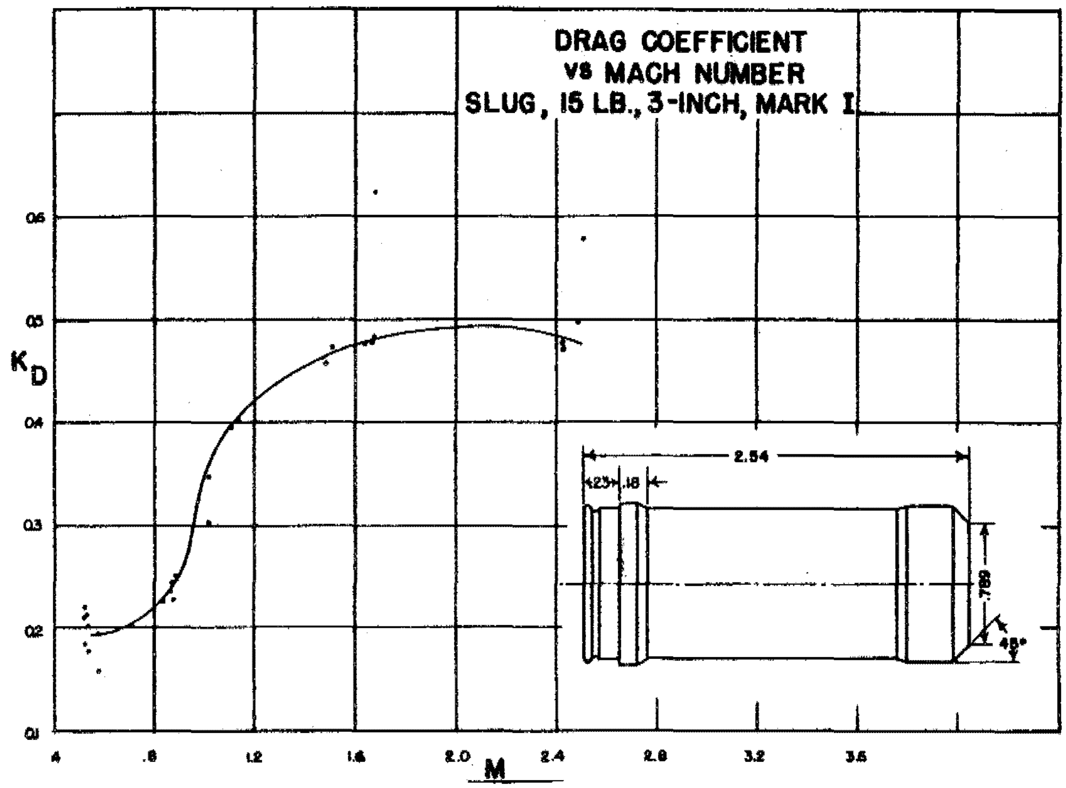
(No bevel; corners rounded with 0.15" radius at head and 0.7" radius at base.)

Resistance firings at Valcartier, Canada, at velocities from 2000 to 3000 ft/sec.

Report: BRL 284 May 43
$K_D = 0.625$

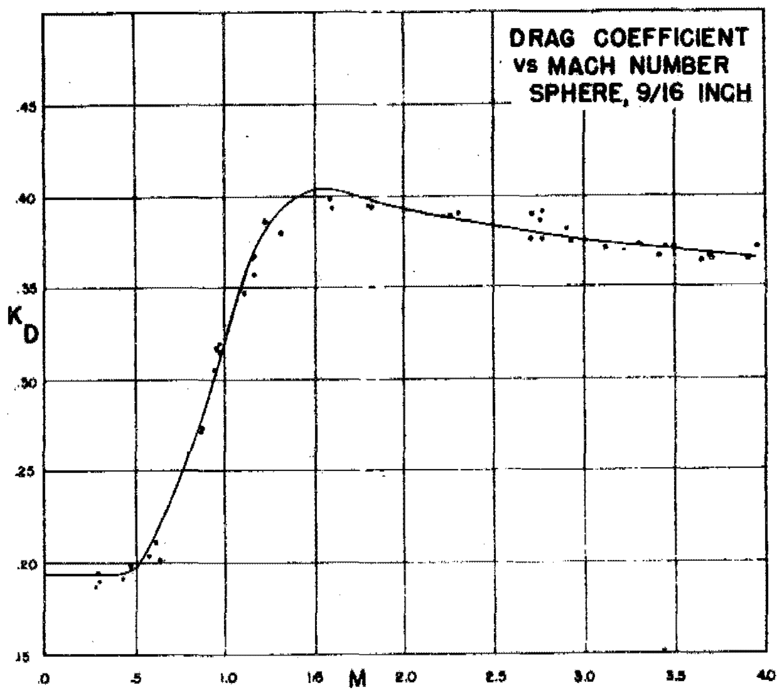

DRAG COEFFICIENT
vs MACH NUMBER
SLUGS WITH 45° BEVEL
K_D
M
3.08
.36
.16
.737
45°

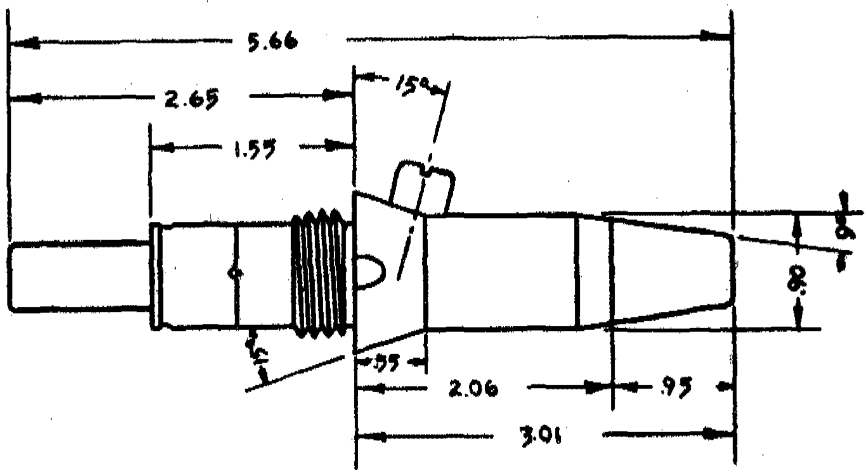

DRAG COEFFICIENT
vs MACH NUMBER
SLUG, 2.4-LB, 57 MM
K_D
M
1.14
.13
.35
.11
45°



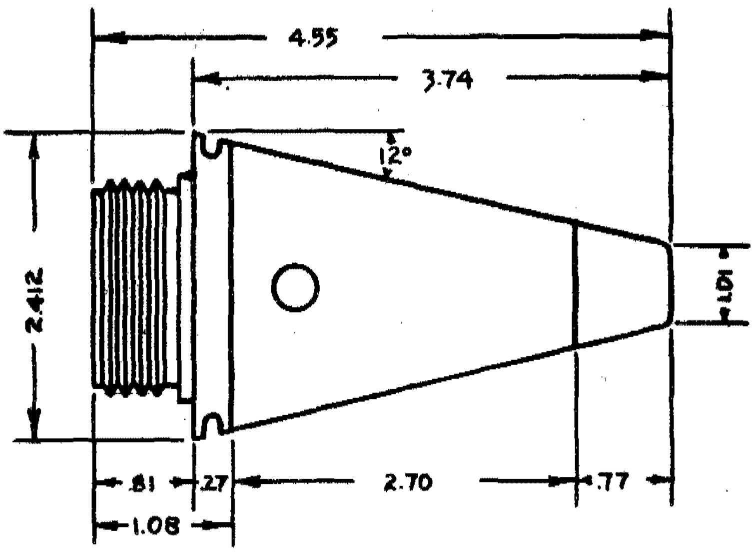
23. Drag of Spheres

Resistance firings of 9/16" smooth spheres in Aerodynamic Range. Report: BRL 514. Graph: K_D vs M (Figs. 4 and 9)

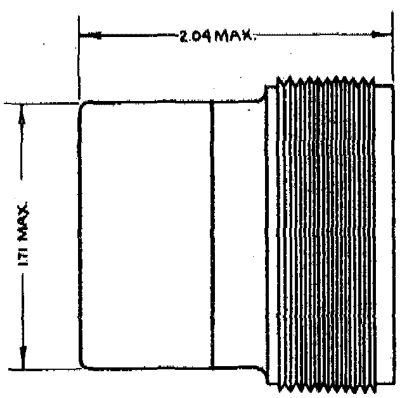




FUZE, P.D., M46 OR M47



FUZE, P.D., M48



BOOSTER, M20

ALL DIMENSIONS IN CALIBERS

24. Point Fuzes

a. Drawings

Fuze, Point Detonating, M46	73-2-126
Fuze, Point Detonating, M47	73-2-157
Fuze, Point Detonating, M48	73-2-140
Fuze, Mechanical Time, M43	73-7-29
Booster, M20	73-2-112

All the following fuzes have the "standard" contour and weigh approximately 1.41 lb. without the booster:

Point Detonating, M48, M48A1 and M48A2

Point Detonating, M51, M51A1, M51A2 and M51A3

Point Detonating, M57

Time and Superquick, M54 and M55

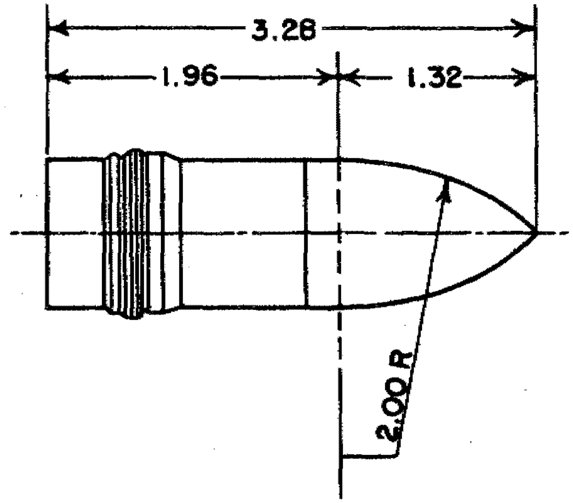
Mechanical Time, M43 and M67

Dummy, M44, M44A1, M59 and M73

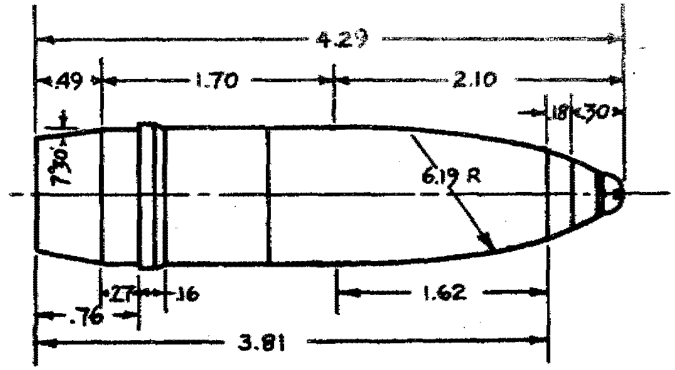
b. Physical Characteristics (BRL Report 163)

Fuze	Booster	Weight Meas. lb.	C.G. to Shoulder in.	A $lb.ft.^2$	B $lb.ft.^2$
P.D. M46	-	0.711	0.59	.0005	.007
P.D. M47	-	0.704	0.53	.0005	.007
P.D. M48	-	1.407	0.58	.0048	.008
M.T. M43	-	1.389	0.86	.0049	.008
- -	M20	0.799	0.95*	.0028	.004
P.D. M48	M20	2.206	-0.08	.0076	.026
M.T. M43	M20	2.188	0.08	.0077	.026

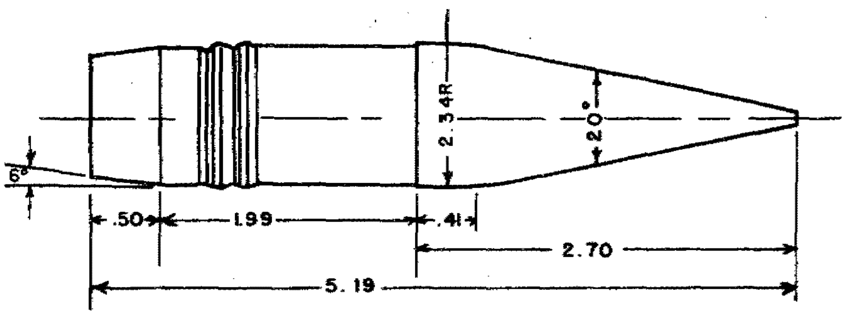
*To rear of booster -Indicates C.G. is behind shoulder



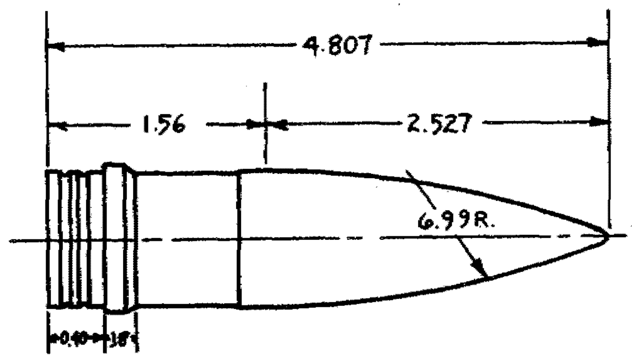
PROJECTILE TYPE I



PROJECTILE TYPE 5

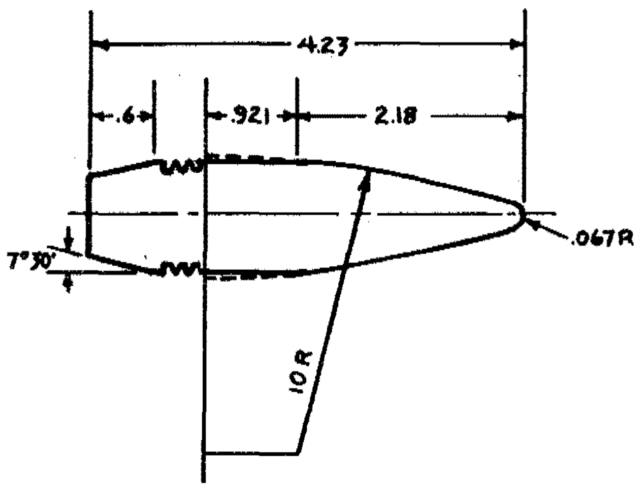


PROJECTILE TYPE 2

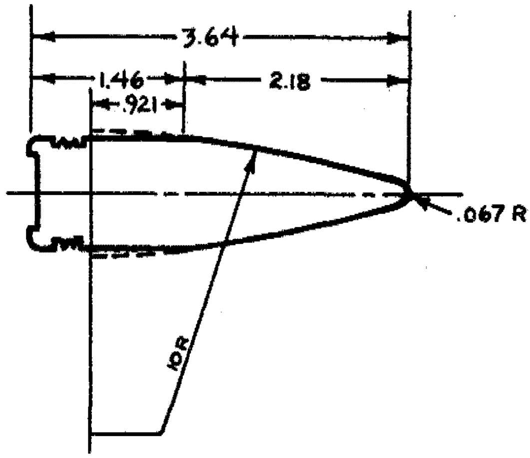


PROJECTILE TYPE 6

ALL DIMENSIONS IN CALIBERS

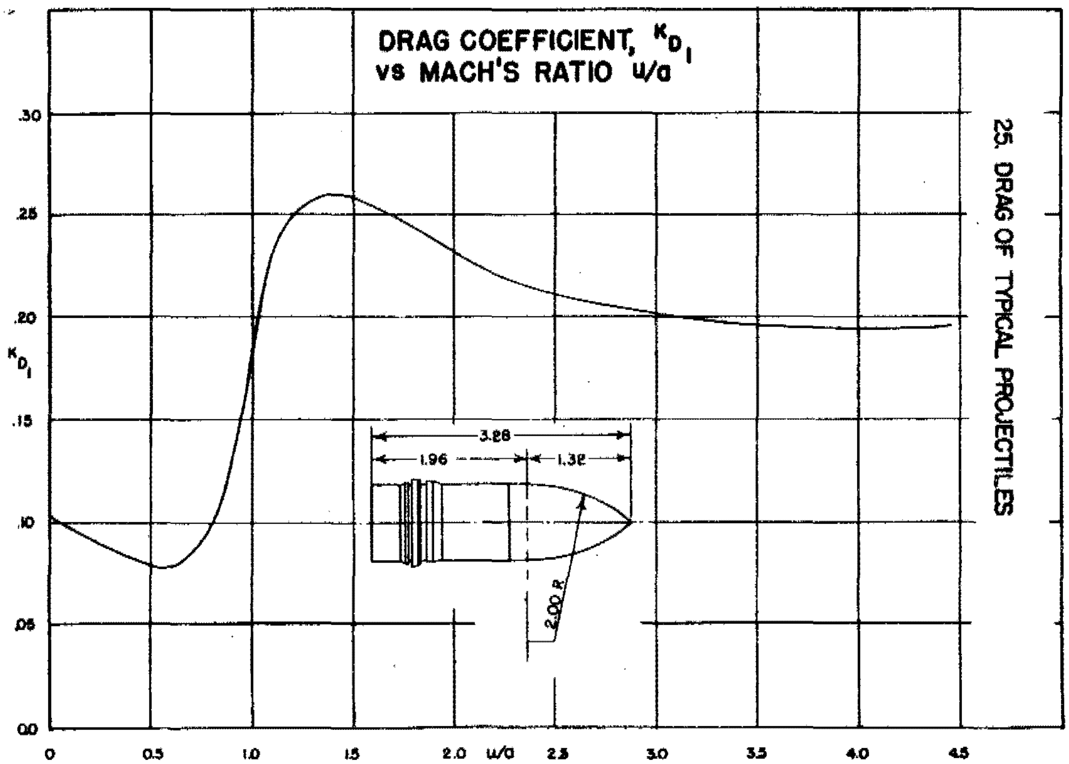


PROJECTILE TYPE 7

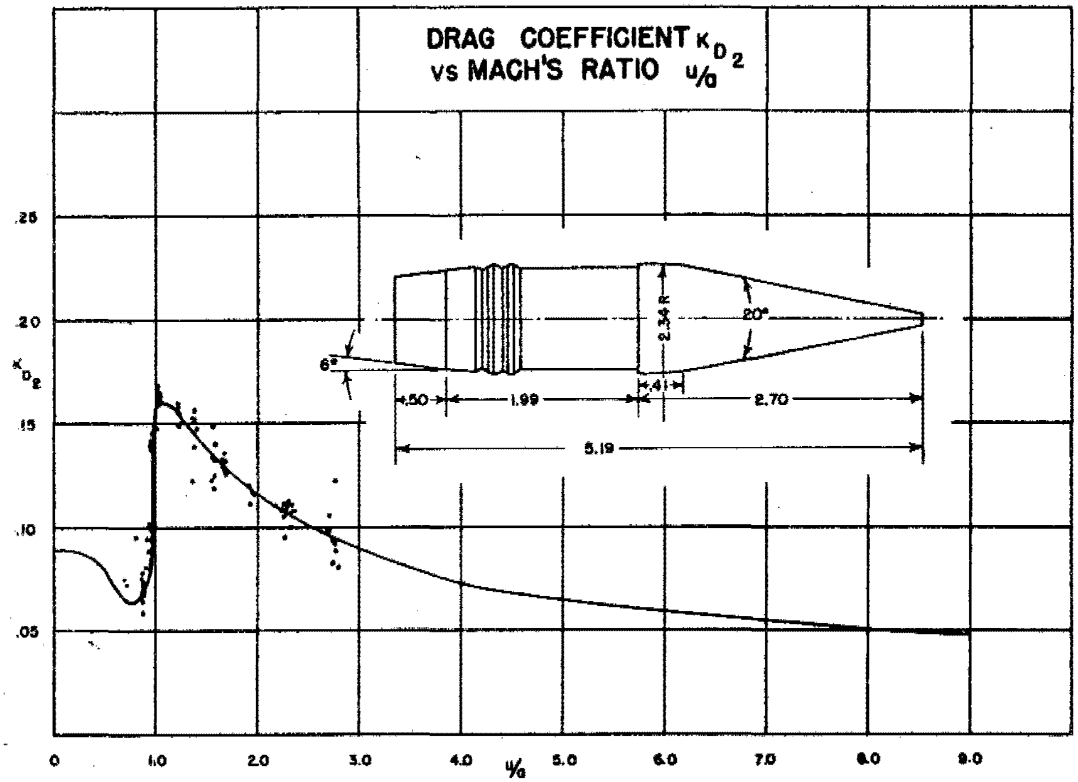


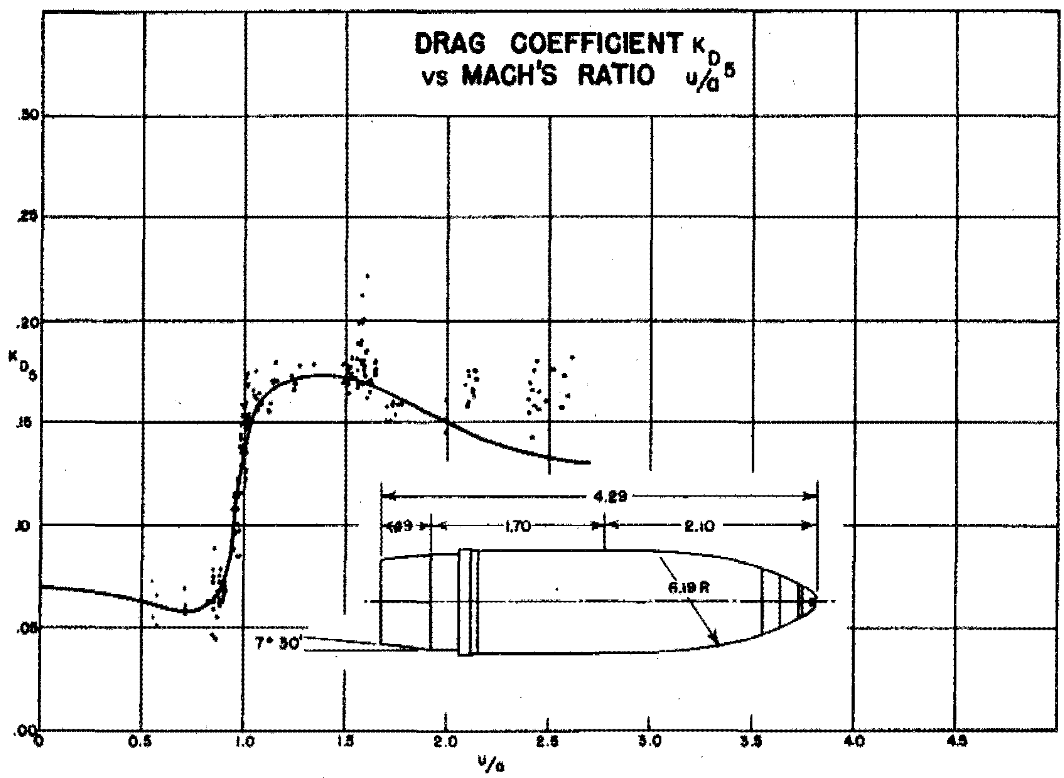
PROJECTILE TYPE 8

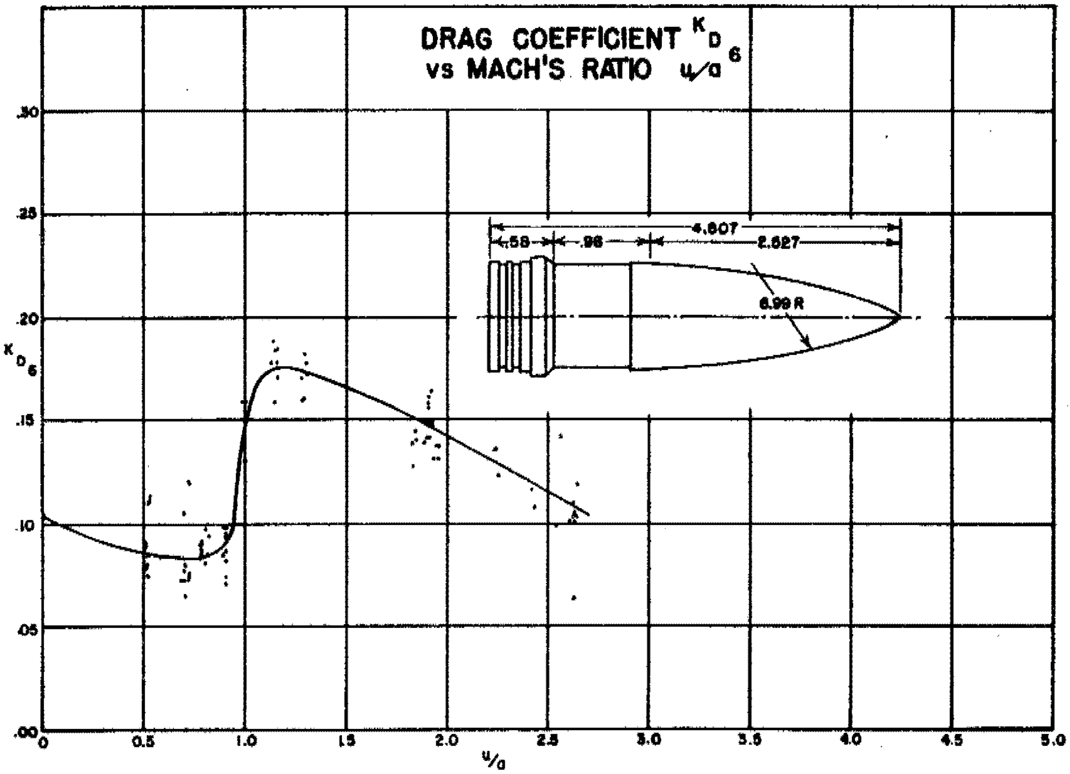
ALL DIMENSIONS IN CALIBERS

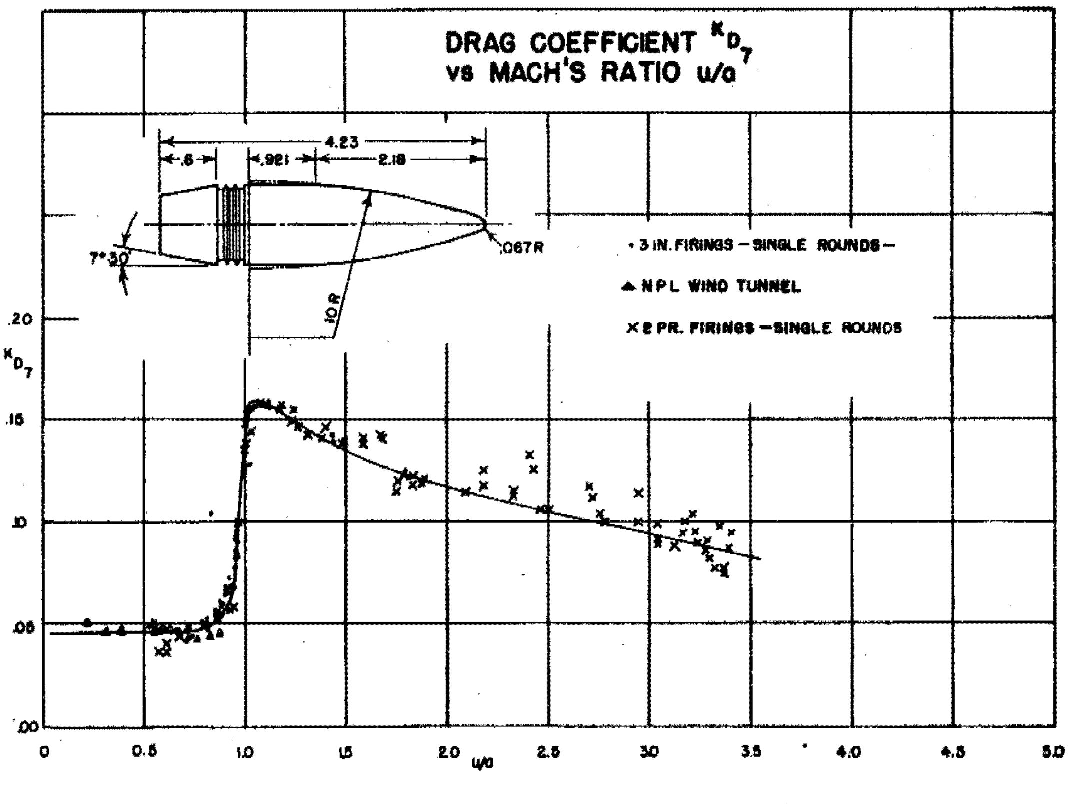


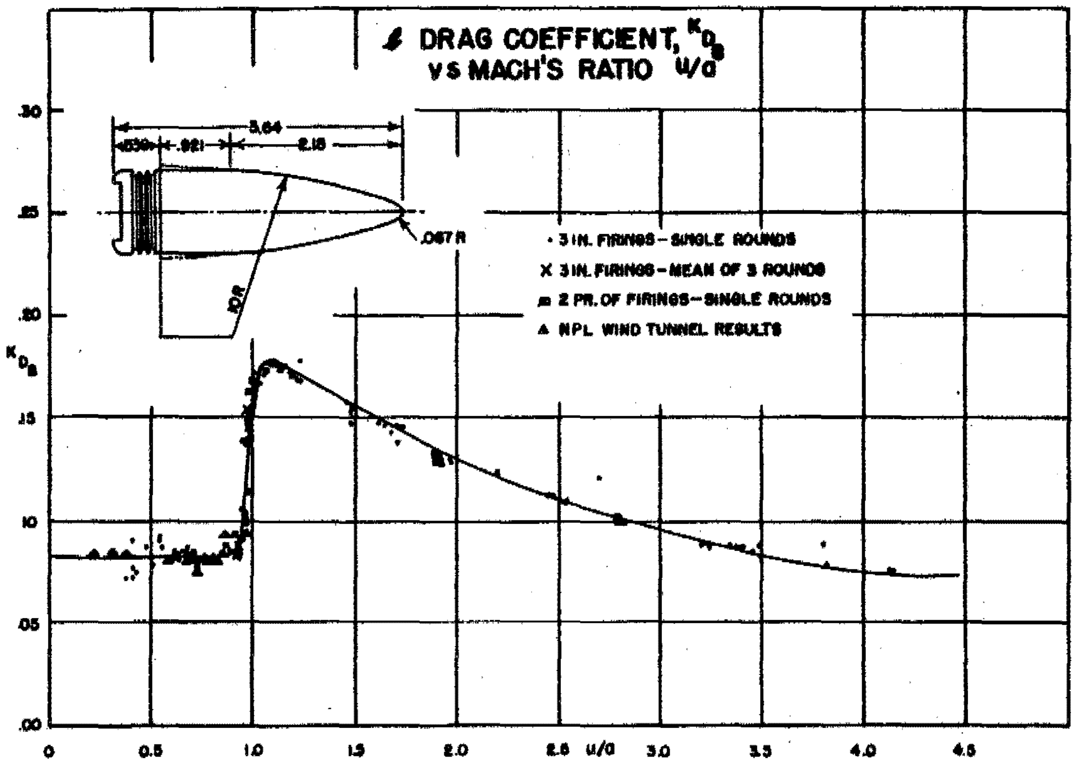
25. DRAG OF TYPICAL PROJECTILES

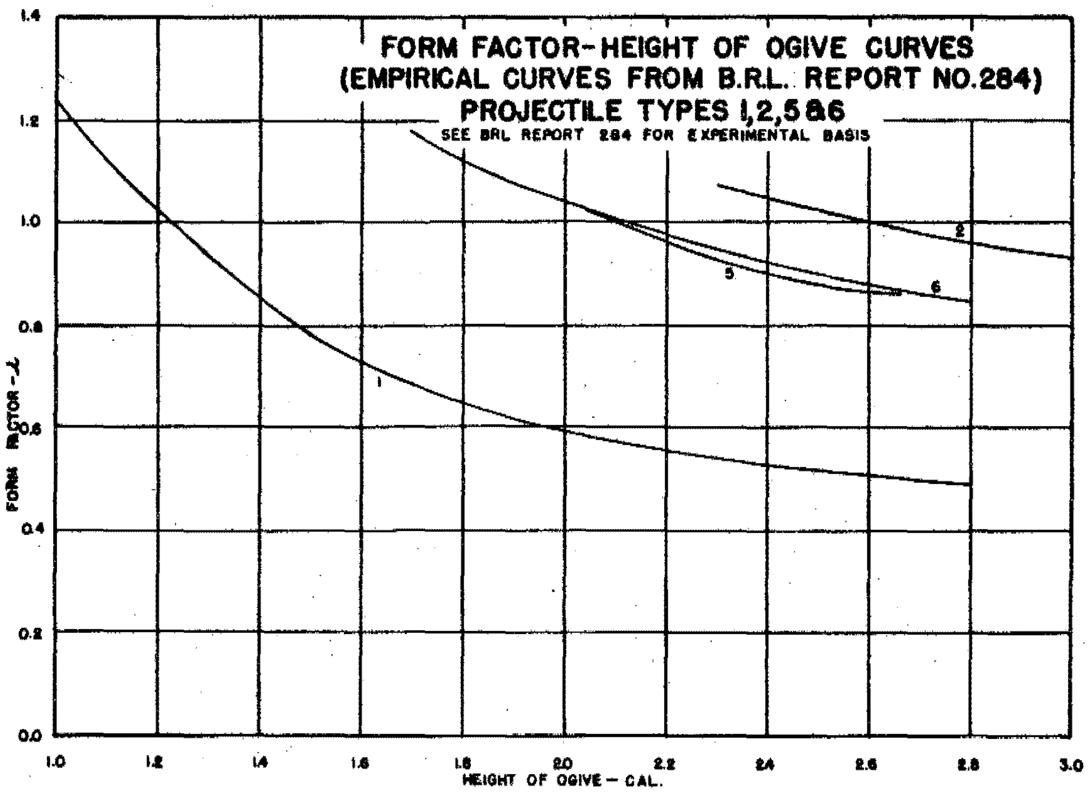

DRAG COEFFICIENT K_{D_2}
VS MACH'S RATIO u/a
.25
.20
.15
.10
.05
K_{D_2}
6°
20°
2.34 R
.50
1.99
.41
2.70
5.19
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
u/a


DRAG COEFFICIENT K_{D_5}
VS MACH'S RATIO u/a
.30
.25
.20
.15
.10
.05
.00
K_{D_5}
4.29
.49
1.70
2.10
6.19 R
7° 30'
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
u/a


DRAG COEFFICIENT K_{D_6}
vs MACH'S RATIO u/a
4.607
.58
.96
2.627
6.99 R
K_{D_6}
.30
.25
.20
.15
.10
.05
.00
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
u/a


DRAG COEFFICIENT K_{D_7}
vs MACH'S RATIO u/a
4.23
.6
.921
2.18
7°30'
.067R
10 R
• 3 IN. FIRINGS — SINGLE ROUNDS —
▲ N P L WIND TUNNEL
× 2 PR. FIRINGS — SINGLE ROUNDS
K_{D_7}
.20
.15
.10
.05
.00
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
u/a


DRAG COEFFICIENT, K_{D_B}
VS MACH'S RATIO u/a
3.64
2.18
.921
.067 R
10 R
• 3 IN. FIRINGS – SINGLE ROUNDS
X 3 IN. FIRINGS – MEAN OF 3 ROUNDS
2 PR. OF FIRINGS – SINGLE ROUNDS
▲ NPL WIND TUNNEL RESULTS
K_{D_B}
u/a


FORM FACTOR–HEIGHT OF OGIVE CURVES
(EMPIRICAL CURVES FROM B.R.L. REPORT NO.284)
PROJECTILE TYPES 1,2,5 & 6
SEE BRL REPORT 284 FOR EXPERIMENTAL BASIS
FORM FACTOR – i
HEIGHT OF OGIVE – CAL.

26. List of Reports on Aerodynamics of Spinning Projectiles

a. Ballistic Research Laboratories Reports

X-113 Hitchcock, H.P., Resistance and Stability of Projectiles: Experimental Methods and Details of Computation

16 Tolch, N.A., The Underground Trajectory and Yaw of the 155mm T2 and T3 Projectiles

27 Hitchcock, H.P., Resistance Functions of Various Types of Projectiles

30 Hitchcock, H.P., Stability Factors of Projectiles (Rev. Sept. 1940)

111 Hitchcock, H.P., Aerodynamic Nomenclature and Formulas, Conversion Factors and Drag Functions

114 Hitchcock, H.P., and Kent, R.H., Application of Siacci's Method to Flat Trajectories

116 Hitchcock, H.P., Firing Sidewise From an Airplane: I. Theoretical Considerations

138 Hitchcock, H.P., Stability of 37mm Shell T12

139 Hitchcock, H.P., Firing Sidewise from an Airplane: II. Effects of a 400 mile per hour Air Speed

150 Hitchcock, H.P., Stability of 90mm Shell T3

154 Kent, R.H., A Determination of the Loss of Spin of Projectiles

162 Hitchcock, H.P., Stability of 155mm Shell Mark III and T2

163 Hitchcock, H.P., Dynamic Data regarding Point Fuzes

165 Hitchcock, H.P., Stability of 90mm Shell T3

166 Hitchcock, H.P., A study of Form Factors of Spinning Projectiles

215 Hitchcock, H.P., Stability of Caliber 0.30 Bullet, A.P. M2

217 Hitchcock, H.P., Stability of 155mm Chemical Shell, Mark VIIA1

225 Hitchcock, H.P., Stability of 37mm H.E. Shell M63, A.P. Shot M51, and Proof Projectile M52

236 Hitchcock, H.P., Stability of 90mm Shell T8

237 Hitchcock, H.P., Stability of 4.7 inch A.A. Shell T5

240 Hitchcock, H.P., Drag on Conical Heads

252 Hitchcock, H.P., Stability of 40mm Shell Mark IIT/L/

257 Hitchcock, H.P., and Kent, R.H., Ballistics of Caliber 0.60 Bullet, A.P., TS4

261 Hitchcock, H.P., Underwater Trajectory of a Spinning Projectile

267 Hitchcock, H.P., Exterior Ballistics of Small Arms Bullets

276 Hitchcock, H.P., Aerodynamics of Small Arms Bullets

278 Hitchcock, H.P., Aerodynamics of Calibers 0.30 and 0.50 Incendiary Bullets M1

283 Hitchcock, H.P., A comparison of British and American Drag Functions and Form Factors

284 Hitchcock, H.P., Form Factors of Projectiles

287 Charters, A.C., and Kent, R.H., The Relation between the Skin Friction Drag and the Spin Reducing Torque

289 Hitchcock, H.P., Drag of Slugs

290 Hitchcock, H.P., Stability of Caliber 0.30 Tungsten Carbide Bullet

26. List of Reports on Aerodynamics of Spinning Projectiles (Con.)

303 Hitchcock, H.P., Stability of Experimental 57mm Shells

338 Hitchcock, H.P., Underground Trajectory of a Spinning Projectile

345 Sterne, T.E., The Effect of Yaw upon Aircraft Gunfire Trajectories

345 Sterne, T.E., Analytical Trajectories for Type 5 Projectiles

354 Hitchcock, H.P., Aerodynamics of 37mm H.E. Shell M54

367 Hitchcock, H.P., Damping of Calibers 0.30 and 0.50 Bullets and 37mm H.E. Shell

369 Thomas, R.N., Retardation of Caliber 0.50 A.P. M2

380 Hitchcock, H.P., Stability of 8-inch H.E. Shell M103

408 Hitchcock, H.P., Loss of Spin and Skin Friction Drag of Projectiles

409 Gurney, R.W., The Optimum Shapes for Shell with regard to Air Resistance

416 Braun, W.F., and Thomas, R.N., 20mm T9E4 AP Determination of Drag Function

425 Braun, W.F., Charters, A.C., and Thomas, R.N., Retardation of Fragments

427 Hitchcock, H.P., Stability of 3-inch Armor-piercing Projectiles

438 Hitchcock, H.P., Yaw and Drift of 37mm Armor-piercing Shots

446 Kelley, J.L., and McShane, E.J., On the Motion of a Projectile with Small or Slowly Changing Yaw

457 Braun, W.F., Charters, A.C., and Thomas, R.N., Aerodynamic Comparison of Gazda, M75, and T9E5 20mm Projectiles

459 Kent, R.H., and McShane, E.J., An Elementary Treatment of the Motion of a Spinning Projectile about its center of gravity

460 Charters, A.C., and Thomas, R.N., Retardation of Tubular Projectiles developed from the 20mm American Ball

507 Nemmers, F.E., The Experimental Basis and Computing Methods used in the Preparation of Firing Table FT 90AA-B-3

514 Charters, A.C., and Thomas, R.N., The Aerodynamic Performance of Small Spheres from Subsonic to High Supersonic Velocities

515 Hitchcock, H.P., Aerodynamics of 20mm Projectiles

543 Thomas, R.N., Some Comments on the Effect of Adding length to the Afterbody of a Square-based, Conical-headed Projectile

567 Stein, H., Comparison of 155mm Shell Designs by means of Model Firings - Part I - Drag

569 Hitchcock, H.P., Spin of 120mm H.E. Shell M73

582 Karpov, B.G., Observational Evidence for the Dependence of Drag on Mach Number at constant Air Speed

597 Morrey, C.B., A Formula for the Representation of Resistance Functions

599 Hoffleit, D., The Drag Coefficients for 105mm Shell, H.E. M1

603 Stein, H., Effect of Various Driving Bands on the Aerodynamic Performance of Projectiles at High Velocities

26. List of Reports on Aerodynamics of Spinning Projectiles (Con.)

b. Ballistic Research Laboratories Memorandum Reports

5	Hitchcock, H.P., Stability of Caliber 0.30 Bullet, SR M1
14	Hitchcock, H.P., Stability of Caliber 0.30 Bullet, Carbine M1
30	Hitchcock, H.P., Effect of Yaw on Accuracy of the Caliber 0.30 Armor Piercing M2 Bullet
38	Hitchcock, H.P., Ballistics of 75mm Chemical Shell T19
54	Charters, A.C., Concentricity of 8" Projectile, M103
60	Hitchcock, H.P., Ballistics of Modified 75mm Chemical Shell T19
89	Hitchcock, H.P., Stability of Modified 75mm Chemical Shell T19
90	Hitchcock, H.P., Ballistics of 37mm H.V.A.P. Shots T24E5 and T24E6
94	Hitchcock, H.P., Yaw of Modified 105mm Smoke Shell M84
99	Hitchcock, H.P., Stability of 75mm Smoke Shell M64
134	Hitchcock, H.P., Ballistics of Sterling Tool Products Co. Projectile
138	Hitchcock, H.P., Ballistics of 20mm H.E.I. Shell T16
149	Hitchcock, H.P., Stability of 90mm A.A. Shell M71 with Fuzes T81 and T81A
154	Hitchcock, H.P., Stability of 75mm H.E. Shell M48 with Fuze T81
171	Hitchcock, H.P., Yaw of 3"/57mm Sabot Type Projectile fired from British 17-pounder Gun
176	Hitchcock, H.P., Ballistics of 20mm A.P. Shot T9 with Plastic Windshield
203	Hitchcock, H.P., Stability and Damping of 75mm H.E. Shell M48
213	Hitchcock, H.P., Stability of 75mm Shell M48 fired from Aircraft Gun
217	Hitchcock, H.P., Stability of 40mm H.E. Shell T7
223	Hitchcock, H.P., Stability of British 20mm Shot, J.A.P./F and J.A.P./W.
245	Hitchcock, H.P., Stability and Damping of Caliber 0.60 Bullet BC-2
246	Hitchcock, H.P., Stability of 57mm H.E. Shells T16 and T18
251	Hitchcock, H.P., and Alexander, A.P., Ballistics of N.D.R.C. 20mm Sabot Type Projectiles
256	Hitchcock, H.P., Yaw and Drift of Caliber 0.50 Bullet, A.P.I. M8
261	Hitchcock, H.P., Stability and Damping of 37mm H.E. Shell T27
265	Hitchcock, H.P., Stability of 105mm H.E. Shell M1
266	Hitchcock, H.P., Stability of 57mm A.P.C. Shot M86
285	Hitchcock, H.P., Stability and Resistance of 4.5-inch Shell M65
287	Hitchcock, H.P., Stability and Resistance of 155mm H.E. Shell M101 with P.D. Fuze T105 Type 6
293	Hicthcock, H.P., Stability of 3-inch H.E. Shell M42 with Reduced Charge
296	Hatch, G., Tables of Impact Velocities for Mobile Artillery Weapons
297	Hitchcock, H.P., Spin Imparted by 75mm Gun T13E1
298	Hitchcock, H.P., Stability and Resistance of 3-inch H.E. Shell M42A1 with P.D. Fuze T105 Type 6
300	Hitchcock, H.P., Stability of the 57mm H.E.A.T. Shell T20 and H.E. Shell T22

26. List of Reports on Aerodynamics of Spinning Projectiles (Con.)

305	Hitchcock, H.P., Stability and Damping of Caliber 0.60 Bullets, Incendiary T1E6 and Ball T32
317	Hitchcock, H.P., Exterior Ballistics of 76mm H.V.A.P. Shot T4 and T4E1
319	Hitchcock, H.P., Stability of 57mm H.E.A.T. Shell T20E1
335	Hitchcock, H.P., Exterior Ballistics of 76mm H.V.A.P. Shot T4E1
336	Hitchcock, H.P., Ballistics of 90mm A.P. Shot T33
347D	Karpov, B.G., Stability Factor of 90mm Shot T30E15, and Form Factors of 90mm Shot T30E15, APC Projectile M82, and AP Shot T33
348D	Hitchcock, H.P., and Karpov, B.G., Stability of Projectiles for the 57mm Recoilless Gun
361	Conti, M.W., Wind Tunnel Testing of 155mm Mortar Projectiles T36
366	Karpov, B.G., Stability Factors of Caliber 0.60 Bullets
368	Hitchcock, H.P., Stability of Projectiles fired forward from Aircraft
371	Karpov, B.G., Japanese Aircraft Armament
401	Hitchcock, H.P., Effect on Drag of Variation in Body Diameter of 105mm H.E. Shell M1
406	Hitchcock, H.P., Stability and Form Factor of German 75/55mm H.E. Shell
410	Goldstein, D.L., Summary of Aerodynamic Data on German Projectiles
411	Hitchcock, H.P., Stability, Form Factor, and Accuracy of 105mm Projectiles
417	Hitchcock, H.P., Aerodynamics of Caliber 0.50 Incendiary Bullet M23

c. Miscellaneous Reports

BRL File K-I-9	Ballistic Research Laboratories, Form Factors of Projectiles
Ord. Program 4982	Boyle, E., Report on Stability Firings with 75mm T3 Shell fitted with M39A2 P.D. And T12 Mechanical Time Fuzes
NPG 3-45	Naval Proving Ground, An Experimental Study of the Air Resistance of Three inch and of 40 millimeter Projectiles
Ord. Program 4684	Boyle, E., Report on Test of Stability of 3" A.A. Shell M42 with Mechanical Time Fuze T12
N.B.S. VI-4/64 26 Jan 45	National Bureau of Standards, Aerodynamic Characteristics of a Full Scale Model of Shell, H.E., 155mm, T36
Ord. Program 4866	Hitchcock, H.P., Report on Resistance of Proof Slugs
NPG S 72-4(49)	Naval Proving Ground, Report on Underwater Trajectories and Penetration of Projectiles

d. Basic Theory

Fowler, R.H., Gallop, E.G., Lock, C.N.H., and Richmond, H.W., The Aerodynamics of a Spinning Shell. Phil. Trans. Royal Soc. London, A 221, 295-387 (1920)

Moulton, F.R., New Methods in Exterior Ballistics. Chap. VI: Motion of a Rotating Projectile. U. of Chi. Press (1926)

Nielsen, K.L., and Synge, J.L., On the Motion of a Spinning Shell. Quar. Applied Math. 4: 201-226 (Oct 1946) (Oct 1946)

For other references, see BRL Reports X-113 and 27

27. List of Illustrations

27. List of Illustrations (Con.)

27. List of Illustrations (Con.)

27. List of Illustrations (Con.)

28. List of Graphs

a. Drag Coefficient vs. Mach Number

28. List of Graphs (Con.)

28. List of Graphs (Con.)

29. Index of Projectiles

a. Square base

(1) Conical or Ogivo-conical Head

(a) Round Point or Small Méplat (dia. less than 1/4 cal.)

29. Index of Projectiles (Con.)

(b) Large Méplat

Shell, H.E., 40mm, T7; Fuze, Detonating, Mark 27

(2) Blunt Ogival Head (not more than 1.75 cal. long)

(a) Round Point or Small Méplat (dia. less than 1/4 cal.)

Projectile Type 1

Bullet, Ball, Cal. 0.60, T32

Bullet, Ball, Cal. 0.60, T32E2

Bullet, A.P., Cal. 0.60, TS4

Bullet, A.P., Cal. 0.60, BC-2

Bullet, A.P., Cal. 0.60, BC-3

Shot, A.P., 20mm, M75

Shot, A.P., 20mm, M95

Shot, A.P., 57mm, M70

Shot, A.P., 3-inch, M79

Shot, A.P., 90mm, M77

Shot, A.P.I., 20mm, T21

Shot, A.P.C., 57mm, M86 w/o windshield

Shot, H.V.A.P., 57mm, T14

Shot, H.V.A.P., 90mm, T38E5 w/o sabot

Shell, H.E., 20mm, T23; Fuze, P.D., T71E4

Shell, H.E., 20mm, M97; Fuze, P.D., M75

Shell, H.E., 37mm, T27; Fuze, B.D., M58

Shell, H.E., 57mm, M306 (T22); Fuze, P.D.

Shell, H.E., 155mm, T24E1; Fuze, P.D., M48

Shell, H.E.I., 20mm, Mark 1; Fuze, Percussion, D.A., No. 253, Mark I/A/

Shell, H.E.I., 20mm, T16; Fuze, P.D., M75

Shell, H.E.A.T., 57mm, T20 Type IIA; Fuze, B.D., T94

Shell, H.E.A.T., 57mm, T20E1; Fuze, B.D., T94E1

Shell, W.P., 57mm, M308 (T23); Fuze, P.D., T119 and M89 (T119E1)

Shell, W.P., 57mm, T23E1; Fuze, Dummy, T126

Shell, Incendiary, 20mm, M96

Shell, Illuminating, 155mm, M118 (T21); Fuze, Dummy, M59

Shell, Illuminating, 155mm, T22; Fuze, M.T., T17

Projectile, Ball, 20mm, T4

29. Index of Projectiles (Con.)

Projectile, Practice, 20mm, M99

Projectile, A.P., 3-inch, Mark 29 w/o windshield or cap

Projectile, A.P.C., 75mm, M61 w/o windshield

Projectile, A.P.C., 75mm, M61 w/o cap or windshield

Projectile, F.S., 3-inch, Mark 3

(b) Large Méplat.

Shell, H.E.A.T., 57mm, M307 (T20E2); Fuze, P.I., T123E1

Projectile, Ball, 20mm, Hispano Gun /A/

Projectile, Proof, 8-inch, T9; Circular Plug

(3) Long Ogival Head (More than 1.75 cal. long)

Projectile Type 6

Projectile Type 8

Bullet, Ball, Cal. 0.30, M2

Bullet, A.P.I., Cal. 0.30, T15

Bullet, A.P.I., Cal. 0.50, T49

Bullet, A.P.I., Cal. 0.60, T39

Bullet, A.P.I.T., Cal. 0.60, T60

Bullet, Incendiary, Cal. 0.60, T36 and T36E2

Bullet, Incendiary, Cal. 0.60, T31

Bullet, Incendiary, Cal. 0.60, T41

Bullet, Tracer, Cal. 0.30, M1

Bullet, Tracer, Cal. 0.50, M1

Bullet, Frangible, Cal. 0.30, M22

Bullet, H.E., Cal. 0.60, T19

Shot, A.P., 20mm, T9E4

Shot, A.P., 57/40mm (J and L Drg A-1944)

Shot, A.P., 90mm, T33

Shot, A.P.C., 37mm, M51

Shot, A.P.C., 40mm, T4E10

Shot, A.P.C., 57mm, M86; Fuze, B.D. M72

Shot, A.P.C., 105mm, T13E2

Shot, A.P.S.V., 37mm, Mark 1

Shot, A.P.D.S., 76/48mm

Shot, H.V.A.P., 155mm, T35

Shell, H.E., 37mm, Mark 2; Fuze, B.D., M38A1

Shell, H.E., 37mm, M63; Fuze, B.D., M58

29. Index of Projectiles (Con.)

Shell, H.E., 37mm, T33; Fuze, B.D., T136

Shell, H.E., 3-inch, M42; Fuze, M.T., M43

Shell, H.E., 3-inch, M42; Fuze, N.D.R.C.

Shell, H.E., 3-inch, M42; Fuze, C.P., M78

Shell, H.E., 105mm, T30E1; Fuze, P.D., M51A4

Shell, H.E.A.T., 57mm, T20; Type IA; Fuze, B.D., T94

Shell, Smoke, 75mm, T19 (B.E.); Fuze, T.SQ., M54

Projectile, A.P., 155mm, M112; Fuze, B.D., M60

Projectile, A.P.C., 75mm, M61; Fuze, B.D., M66A1

Projectile, A.P.C., 3-inch, M62; Fuze, B.D., M66A1

Projectile, A.P.C., 90mm, M82; Fuze, B.D., M68

Projectile, Illuminating, 3-inch, Mark 25; Dummy Nose Plug

Projectile, 3-inch, Mark 27; Dummy Nose Plug

Projectile, Common, 6-inch, Mark 20

(4) Slug

(a) Beveled Head

Projectile, Proof, 37mm, M52

Slug, 1.25 lb., 37mm

Slug, 2.40 lb., 57mm

Slug, 9.00 lb., 75mm (Mark 1 modified)

Slug, 11.72 lb., 75mm, Mark 1

Slug, 15.96 lb., 75mm, Mark 1

Slug, 14.40 lb., 75mm, T13

Slug, 13.94 lb., 75mm, T15

Slug, 12.70 lb., 3-inch

Slug, 12.79 lb., 3-inch

Slug, 15.00 lb., 3-inch, Mark 1

(b) Flat Head

Shot, Flat Head, 40mm (Canadian)

(c) Protruding Rod

Shot, H.V.A.P., 3-inch, T4 w/o windshield, 1-inch rod

Shot, H.V.A.P., 3-inch, T4 w/o windshield, 1/2-inch rod

(d) Spool-shaped

Projectile, Proof, 155mm, simulating the H.V.A.P. Shot T35

29. Index of Projectiles (Con.)

b. Boat-tail

(1) Conical or Ogivo-conical Head

(a) Round Point or Small Méplat (less than 1/4 cal.)

Projectile Type 2

Shell, H.E., 57mm, T16; Fuze, Dummy, T66

Shell, H.E., 75mm, T38; Fuze, P.D., M48

Shell, H.E., 120mm, M73; Fuze, M.T., M61

Shell, H.E., 120mm, M73; Fuze, Exp., T75E6

Shell, H.E., 8-inch, M103; Fuze, P.D., M51 Mod. 1

Shell, H.E.A.T., 75mm, M66; Fuze, B.D., M62 or T93

Shell, H.E.A.T., 75mm, T39; Fuze, B.D., M62

Shell, H.E.A.T., 105mm, M67; Fuze, B.D., M62

Shell, H.E.A.T., 105mm, M67E1; Fuze, B.D., M62A1

Shell, Practice, 105mm, M67; Fuze, Dummy, T121

(b) Large méplat

Shot, A.P.C., 37mm, M59 (120° vertical angle)

Shell, Q.F.H.E., 40mm, Mark 2 T/L/; Fuze, P.D., M64 and M64A1

Shell, Q.F.H.E., 40mm, Mark 2 T/L/; Plug, wood

Shell, Practice, 40mm, M91

(2) Ogival Head

(a) Round Point or Small Méplat (dia. less than 1/4 cal.)

Projectile Type 5

Projectile Type 7

Bullet, Ball, Cal. 0.30, M1

Bullet, Ball, Cal. 0.50, M1

Bullet, A.P., Cal. 0.30, M2

Bullet, A.P., Cal. 0.50, M2

Bullet, A.P.I., Cal. 0.50, M8

Bullet, A.P.I.T., Cal. 0.50, T28

Bullet, A.P.I.T., Cal. 0.50, T63

Bullet, A.P.T., Cal. 0.50, T38

Bullet, A.P.T., Cal. 0.50, T38E1

Bullet, Incendiary, Cal. 0.50, M1

Shot, A.P., 37mm, M74

Shot, A.P., 37mm, M80

Shot, A.P., 75mm, M72

29. Index of Projectiles (Con.)

Cal. 0.50 Model of 155mm H.E. Shell M101
Cal. 0.50 Model of 155mm H.E. Shell P1
Cal. 0.50 Model of 155mm H.E. Shell P2
Shell, H.E., 37mm, T2; Fuze, Dummy, T30
Shell, H.E., 75mm, M48; Fuze, P.D., M39A2
Shell, H.E., 75mm, M48; Fuze, M.T., M43
Shell, H.E., 75mm, M48; Fuze, P.D., M48
Shell, H.E., 75mm, M48; Fuze, N.D.R.C.
Shell, H.E., 75mm, M48; Fuze. C.P., M78
Shell, H.E., 90mm, M58; Fuze. M.T., M43
Shell, H.E., 90mm, M58; Fuze, P.D., M48
Shell, H.E., 90mm, M71; Fuze, 21-sec A.A., Mark III
Shell, H.E., 90mm, M71; Fuze, M.T., M43
Shell, H.E., 90mm, M71; Fuze, N.D.R.C.
Shell, H.E., 90mm, T15; Fuze, Dummy, M44A2
Shell, H.E., 105mm, M1; Fuze, P.D., M48
Shell, H.E., 105mm, M1; Fuze, Dummy, M59
Shell, H.E., 105mm, M1; Fuze, C.P., M78
Shell, H.E., 4.5-inch, M65; Fuze, P.D., M48
Shell, H.E., 4.5-inch, M65; Fuze, P.D., M51
Shell, H.E., 4.5-inch, M65; Fuze, N.D.R.C.
Shell, H.E., 4.5-inch, M65; Fuze, C.P., M78
Shell, H.E., 155mm, Mark 3; Fuze, P.D., M46
Shell, H.E., 155mm, M101; Fuze, P.D., M51A1
Shell, H.E., 155mm, M101; Fuze, P.D., M48
Shell, H.E., 155mm, M101; Fuze, C.P., M78
Shell, H.E., 155mm, M101; Fuze, N.D.R.C.
Shell, H.E., 155mm, M107; Fuze, P.D., M51
Shell, H.E., 155mm, T36; Fuze, P.D., M48
Shell, H.E., 8-inch, M106; Fuze, P.D., M51
Shell, H.E., 8-inch, M106; Fuze, N.D.R.C.
Shell, H.E., 240mm, M114; Fuze, P.D., M51
Shell, H.E., 240mm, M114; Fuze, N.D.R.C.
Shell, Chem., 75mm, M64; Fuze, P.D., M48
Shell, Chem., 105mm, M60; Fuze, P.D., M48
Shell, Chem., 155mm, Mark 7A1; Fuze, P.D., M57
Shell, Smoke (BE), 105mm, M84; Fuze, T.SQ., M54

29. Index of Projectiles (Con.)

Shell, Illuminating (BE), 105mm, M314 (T16); Fuze, T.SQ., M54

(b) Large Méplat

Shell, H.E., 37mm, M54; Fuze, P.D., M56

Shell, H.E., 75mm, Mark 1; Hexagonal Plug

Shell, H.E., 90mm, M58; Plug, Closing, 75-14-309E

Shell, H.E., 105mm, M1; Circular Plug

Shell, H.E., 105mm, M1; Hexagonal Plug

Shell, H.E., 4.5-inch, M65; Plug, Closing, 75-14-309E

Shell, H.E., 4.5-inch, M65; Circular Plug

Shell, H.E., 120mm, M73; Plug, Closing, 75-14-309E

Shell, H.E., 155mm, Mark 1; Wood Plug

Shell, H.E., 155mm, M102; Hexagonal Plug

Shell, Chem., 75mm, Mark 2; Round Wood Plug

Shell, Practice, 37mm, M55A1; Plug, Closing, 75-14-309A

c. Sphere, 9/16-inch.

H. P. Hitchcock

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TSDIN FORM 60 A (13 MAR 47)

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ABSTRACT

The report contains the physical and aerodynamic data of spinning projectiles (excluding spin stabilized rockets) which have been obtained experimentally in the U.S. during the past decade. Data are arranged according to caliber; then separate paragraphs are devoted to drag of slugs, drag of spheres, characteristics of point fuzes, and drag of typical projectiles. In ordinary projectiles of each caliber, a sketch of projectile is given showing principal dimensions in calibers and numbers of official drawings. Physical characteristics including weight and distance from base to center of gravity are presented.